ingestion (sizes, quantities and occurrence rates) and consequences. The results of this initial data analysis were presented to the FAA in AIA reports dated October 17, 1986, and November 10, 1988. The results of the analysis were compared to the historical design standards and certification bases for the family of engines comprised in the database. As a result of that analysis, the industry study group identified bird encounter threats more severe than were addressed in either engine design practices of the time, or in part 33. Subsequently, additional data was collected and analyzed for small and medium sized turbine engines which were not represented within the initial database. This data is contained within FAA Technical Center reports dated December 1990, December 1991, and July 1992.

In addition to the industry study and data analysis for large engines, industry also addressed the service experience of the small turbojet and turbofan engine designs. With the rapid expansion of the turbojet and turbofan engine powered business jet fleet in the late 1960's and early 1970's, a significant number of multiple engine power loss accidents occurred due to flocking bird ingestion. Careful review of these turbojet and turbofan engine events showed that the flight crews had often flown through very large flocks of birds with ingestion of many birds in each engine which resulted in multiple engine flameouts.

At the time, the FAA engaged in a discussion with engine manufacturers, and concluded that mechanical design changes alone would not alleviate the adverse affects of severe inlet blockage caused by massive flocking bird ingestions. The FAA and the manufacturers, then embarked upon a campaign to better inform the aviation community regarding bird hazards and necessary airport controls, and the accident rate due to bird ingestion decreased markedly. Additionally, the FAA amended part 33 effective October 31, 1974 (amendment 33-6), to require manufacturers to incorporate significant design improvements to address the typical flocking bird threat. The service experience of business jet engine designs that meet the standards of amendment of 33-6 indicates that resistance to bird ingestion induced damage has greatly improved over earlier service history.

A via tion Rulemaking Advisory Committee (ARAC) Project

The FAA is committed to undertaking and supporting the harmonization of part 33 with JAR-E. In August 1989, as a result of that commitment, the FAA Engine and Propeller Directorate participated in a meeting with the Joint Aviation Authorities (JAA), AIA, and AECMA. The purpose of the meeting was to establish a philosophy, guidelines, and a working relationship regarding the resolution of issues identified as needing to be harmonized, including some where new standards are needed. All parties agreed to work in a partnership to jointly address the harmonization effort task. This partnership was later expanded to include the airworthiness authority of Canada, Transport Canada.

This partnership identified seven items as the most critical to the initial harmonization effort. The proposed bird ingestion standards represent one item on the list of seven, and, therefore, represent a critical harmonization effort.

The bird ingestion standards proposal was selected as an ARAC project, and assigned to the Engine Harmonization Working Group (EHWG) of the Transport Airplane and Engine Issues Group (TAEIG) on December 11, 1992 (57 FR 58840). On April 9, 1997, the TAEIG recommended that the FAA proceed with the proposed rulemaking and associated advisory material even though one working group member disagreed with the proposal. This proposed NPRM reflects the ARAC recommendations on that rulemaking.

The basis for the development of this proposed rule is to (1) minimize the threat to aircraft from the historical bird threat to one or more engines; and (2) substantiate that the engine design provides at least a 1E-8 per aircraft cycle freedom from risk of a hazardous consequence to the aircraft due to the bird ingestion threat. For all bird ingestion threats, a hazardous consequence occurs when the resulting damage to the engine results in an unsafe condition specified in § 33.75; and in the specific case of small and medium birds, where insufficient power is retained to provide engine run-on capability to ensure a safe landing.

Medium bird ingestion criteria for small engines was established consistent with corresponding criteria for medium and large engines, which is freedom from multi-engine power loss events at a rate of 1E-8 per aircraft cycle. These criteria are based on the assumption that current standards for airport certification will be maintained, that the historical environment will not worsen, and that airport operators and pilots will maintain at least their current awareness of the bird ingestion threat.

The development of this proposal recognizes that each engine design must address the bird ingestion threat, without regard to the ingestion capability of previous designs as described in the service history database. Unless the proposal addresses the actual in-service bird ingestion threat, there can be no assurance that future designs would continue to exhibit acceptable capability.

The results of this data analysis are summarized as follows:

1. Dual engine power loss events with hazardous consequences (flocking birds of all sizes) have occurred at the rate of 3.2E-7 occurrences per aircraft cycle for large high-bypass ratio engines. This finding reflects service data for the 20-year period through 1987.
2. Multiple engine ingestion of flocking birds up to 2.5 lbs. has occurred at the rate of 1E-6 occurrences per aircraft cycle for large high-bypass ratio engines.
3. Single engine power loss events due to ingestion of birds smaller than the current § 33.77 standard has occurred at a rate of 1E-6 or greater per aircraft cycle for all large high-bypass ratio engines.
4. Single engine ingestion of a large bird (4-8 lb. based on inlet area) has occurred at a rate up to 3.1E-6 occurrences per aircraft cycle.
5. Dual engine ingestion of flocking birds up to 1.5 lbs. has occurred at a rate of 1E-8 occurrences per aircraft cycle for small engines.
6. Bird ingestion service difficulty issues relating to engine models not type certificated to the proposed requirements, can safely be addressed by continued airworthiness control programs.

This proposal recognizes the need to design a conservative test, while at the same time being representative of in-service combinations of critical ingestion parameters. Since testing for all possible combinations of events is impractical, a degree of conservatism was called for in a single test demonstration. That conservatism was incorporated into the proposed tests by selecting bird sizes or quantities, or both, among the most severe encountered within the 1E-8 service history, as well as requiring critical test parameters to be at worse case combination (speeds and aim points). It is therefore reasonable to accept a satisfactory test outcome which is conservative with respect to the various combinations of critical test parameters, and their demonstrated rate of occurrence in service.

An example of parametric rule consideration during regulatory tests is the question of multiple bird impacts to the same rotor blade. The likelihood of multiple impacts on one blade is dependent on the number of birds, the number of blades, and the exposed frontal area. The aircraft and engine manufacturers have stated that it is not always possible to achieve a uniform distribution of birds across the complete face of the engine in a single engine test. This situation could result in multiple birds striking the same blade, and may be viewed as unrepresentative and overly conservative based on probabilities appropriate to a random ingestion (averaged over a multiple ingestion event).

With respect to the flocking bird threat, this proposal considers the potential affects on the engine associated with the size and number of birds, and operating conditions of pertinent aircraft. For smaller flocking birds (0.5 to 1.5 lb.), greater quantities of birds may be ingested when compared to quantities associated with larger size flocking birds. The proposed tests would require the applicant to consider both the affects of bird size on the impact loading of the engine components, as well as the quantity ingested with potential multiple target locations being struck on the face of the engine. Additionally, the applicant would have to consider the potential affects of the ingestion and the resultant damage to the front face of the engine, as they affect the engine core and engine's run-on capability.

Analysis of the service record of engines with an inlet surface area larger than 2,000 square-inches over a 20-year period has led to the conclusion that some additional certification standards are required. The proposed standards are intended to reduce the risk of a dual engine power loss from current in-service rates. The improvement goal is approximately 1E–8 or better per aircraft departure. The data analysis has identified specific flocking bird threats up to approximately 8 lb. size (Canada goose). Therefore, it is the intent of this proposed rule to strengthen the engine airworthiness requirements by increasing the medium bird ingestion requirements from 1.5 to 2.5 lb. birds (representing the herring gull threat) and, by increasing the single large bird ingestion requirements, to address bird threats from 4 to 8 lb. (Canada goose). (The term "1E–8" is a standard scientific notation.)

The FAA recognizes that flocking birds larger than those specified in this proposed rule may be encountered. While available engine technology alone may not provide mitigation of this risk to approximately 1E–8 or better per aircraft departure, mitigation of this threat may be provided by compliance with the more severe requirements of this proposal. In addition, the introduction of aircraft that can be operated with up to a 50-percent power loss from each engine (large, twin engine, transport aircraft) and improved airport bird control methods and awareness will further address this very large bird threat. The data summary supporting this conclusion for medium to large high bypass engines (70 to 100 inch inlet diameter except as noted) is as follows:

Multiple engine ingestions of birds greater than 1 .O lb. = 2.1E–6*
Multiple engine ingestions of birds greater than 1.5 lb. = 1.4E–6*
Multiple engine ingestions of birds greater than 2.5 lb. = 1.4E–7**
Multiple engine ingestions of birds greater than 4.0 lb. = 8.8E–8**
Multiple engine ingestions of birds greater than 2.5 lb. = 9.5E–8***

*Data collection period 1970– 1987
* *Data collection period 1970– 1995
* **Data collection period 1970– 1995 for 60 to 100 inch diameter inlets

The data also suggests that the number of birds likely to be ingested into all engines during a flock encounter was inversely proportional to the size of birds. These data were examined on an exceedence basis, and show that 95-percent of the time no more than the following quantities of birds would be ingested into all engines on an aircraft during a flock encounter. As an example, the following quantities of birds ingested for engines in the 6,000 square-inch class are as follows:

Weight of bird	Number of birds
1.0–1.5	3
1.5–2.5	3
2.5+	2

Considering the desire to evaluate multiple critical target locations on the face of the engine, this proposal selects a size of flocking bird that corresponds to a bird quantity of two or more birds. However, the FAA recognizes that there would be a residual risk of encounter of potentially larger bird sizes than specified in this proposed rule, and possibly greater quantities of birds than specified in this proposed rule. This proposal, however significantly increases the severity of the certification demonstration and provides a reduction in risk of a dual engine power loss due to flocking bird ingestion of any size and quantity.

In considering single large bird threats for sizes greater than that demonstrated under the medium flocking bird threat to multiple engines, the data analysis attempted to quantify exposure rates for birds weighing 4 lbs. and up as a function of inlet throat area. Data from a series of FAA Technical Center reports published between 1990 and 1992 were used, in addition to the original AIA studies.

The data showed that small and medium engine sizes up to an inlet throat area of 2,100 square-inches had a relatively constant threat from birds greater than 4 lbs. at approximately 5E–7 ingestions per aircraft departure. Reports from the manufacturers also showed that this size of engine was more likely to ingest only portions of large birds, due to the much higher probability that an ingested bird may not enter the inlet on the engine centerline and, therefore, would strike the inlet structure and be dismembered before reaching the engine rotor blades. This conclusion is further substantiated by the absence of reports of unsafe engine shutdown due to single large birds greater than 4 lbs. for engines in this size range.

For engines with inlets larger than 2,100 square-inches, the rate of exposure to single large birds tracked roughly with increasing inlet size. The exposure rate for birds larger than 4 lbs. for the large population of engines with inlet surface areas in the 2,100 to 6,000 square-inch range was 1.5E–6 ingestions per aircraft departure. Review of the revenue service data however showed that medium and large turbofans exposed to single large birds above 4 lbs. have demonstrated safe shutdown characteristics as defined under § 33.75 even with bird sizes up to 15 lbs. The rate of unsafe shutdown occurrences in accordance with § 33.75 criteria was approximately one event per 120 occurrences. This unsafe shutdown rate was attributed to the blade-out containment test requirements of § 33.94 constituting a more severe test relative to safe shutdown criteria for almost all engines.

The intent of this proposed rule is to establish the single large bird size as a function of inlet surface area greater than 2,100 square-inches at a level where the exposure to birds beyond that specified in this proposed rule would be in the range of 1E–6 to 1E–7 ingestions per aircraft departure. This coupled with the prior service history record of satisfactory shutdown experience when exposed to very large birds, provides a potential improvement for hazardous consequences to continued safe flight into the extremely remote range of probability, i.e., 1E–7 to 1E–9.

This proposed rule conservatively establishes the single, large bird requirement for engines with inlet surface areas in the 2,100 to 6,000 square-inch range at 6 lbs. where the average exposure to larger birds was 8E–7 ingestions per aircraft departure. For engines with inlet surface areas greater than 6,000 square-inches, the requirement was increased to 8 lbs. to maintain an equivalent margin of safety.

The selection of the 200-knot ingestion speed for the large bird test was based on consideration of impact loading on the engine front stage blading. It was determined that for most current turbine engine designs, conducting the test at 250-knots (maximum allowed airspeed below 10,000-feet altitude) would likely result in a relatively low blade impact vector, which results in less than maximum bird impact forces on the blade(s). Coupled with the specified bird mass variations with engine inlet size, the proposed rule would fix the ingestion speed at 200-knots, and would require applicants to perform an analysis to determine the critical spanwise target location for a particular engine application.

Large turbofan engines certified to the medium bird requirements of § 33.77, amendment 33-6, which requires bird velocities of 250-knots, sustained in-service blade fractures and loss of power for ingested bird weights less than those demonstrated for certification test. Second generation turbofan engines certified under § 33.77, amendment 33-10, used bird velocities which were equivalent to V_2 (takeoff safety speed) for the application aircraft (160 to 180-knots for the large transports). While the in-service record was significantly improved, these second generation engines were still experiencing blade fractures and power loss for bird weights less than the certification standard.

Engine ingestion parameters contributing to more than 50-percent power loss events were evaluated by AIA and AECMA. The most critical of the parameters evaluated which affected power loss were found to be bird weight, bird velocity, aiming point, and engine power setting. Each of these critical ingestion parameters have been evaluated in the proposed rule to determine the most severe conditions under which the medium bird test should be conducted.

The velocity to be used for the medium bird test was first established as the most critical velocity between V_1 (takeoff decision speed) and 250-knots indicated airspeed (KIAS) in order to cover the full range of takeoff and initial climb conditions that were considered to be potentially hazardous to the aircraft. In recognition of commuter and small business jet applications, the criterion was modified to reflect the fact that 250 KIAS was above the normal takeoff and climb speeds for this class of aircraft. A compromise criterion was chosen which required the medium bird ingestion velocity to be the most critical velocity between V_1 and the velocity reached at 1,500-feet above ground level (AGL).

Bird strike data for rotorcraft are not as comprehensive as that available for fixed wing aircraft, probably for a variety of reasons associated with reporting standards, forward speed, low altitude operations, and the extensive use of inlet protection or inherent installation shielding on rotorcraft. The following helicopter bird ingestion data was reviewed in support of this proposal: (France) Direction Generale de L'Aviation Civile (DGAC), 1983 through 1990; (United Kingdom) Civil Aviation Authority (CAA), 1976 through 1987, and 1989 through 1990; (U.S.A.) FAA, 1985 through 1990; (Canada) Transport Canada, 1981 through 1989; and International Civil Aviation Organization (ICAO), 1981 through 1989. The review showed reports of more than 600 bird strike events, but only four events were reported as engine ingestions, and none were multiple events. Many of the 600 events involved flocks of small birds making engine ingestion very probable. Since there are no reports of significant power loss or mechanical damage it can be assumed that these ingestions had no affect on the engine.

The FAA did not find any records of hazardous events or service difficulties associated with engine bird ingestion in multi-engine rotorcraft operation. To require a rotorcraft engine to demonstrate medium bird ingestion capability will impose an unnecessary burden upon the design while producing no measurable safety benefit. The FAA, therefore, proposes that engines intended for use in multi-engine rotorcraft need not show compliance with the medium bird ingestion requirements of this proposed rule.

With respect to the actual test day conditions when demonstrations are made, this proposal considers the variability of engine performance as a function of changing ambient conditions. For example, substantial variations in engine rotor speed may take place between test demonstrations performed on cold days versus testing on hot days. These variations in rotor speed could in turn lead to variations in resulting damage, engine power, and operating characteristics. Even with no variation in blade damage, significant variations in power or other characteristics could be expected for conditions considerably different than for the test demonstration. Therefore, the FAA proposes to allow the actual test day ambient conditions and engine pretest conditions to vary, permitting equal flexibility among applicants and avoid conduct of engine tests in unrepresentative conditions which could lead to cycle mismatches. However, each applicant must account for these potential variations by extrapolation to other conditions specified in the type design. From the standpoint of power and operating characteristics, the applicant must show that the engine condition following bird ingestion can be extrapolated to that specified in the type design. Therefore, the FAA determined that the sea level, hot day, corner point represents a worst case set of ambient conditions for which to substantiate bird ingestion capability for both single large and flocking birds. From the standpoint of potential limit exceedences, the applicant must consider the worst performing production engine that is allowed by the type design.

The current rules consider the possibility of imminent failure following a bird ingestion encounter producing damage. Considering this possibility, the proposed rule recognizes the need to provide a positive margin to demonstrate run-on capability and the ability for an engine to safely function throughout a conservative time for an emergency return to the airport of departure immediately following a bird ingestion event. This scenario includes a recognition that the most critical encounters typically occur during heavy weight takeoffs and may require dumping of fuel before returning to land. During this period, it may be necessary to operate damaged engines throughout their operating cycle, including a need to make a go-around due to debris or equipment on the runway. This proposed rule would require the applicant to demonstrate the engine's ability to operate satisfactorily during such circumstances. However, this proposal also recognizes that it is not possible to extend this demonstration to include all possible conditions occurring throughout a flight, particularly should the pilot decide to continue the flight to its originally intended destination. Lastly, considering the probable nature of bird ingestions, compliance with § 33.75 does not allow for circumstances which could lead to a hazardous failure as defined under that section. Therefore, seemingly normal operation of multiple damaged engines will not likely result in the failure of multiple engines within the same flight. For these reasons, there is no requirement within this proposed rule to further consider imminent failure after bird ingestion.

The EHWG also considered differences between part 33 and JAR-E with respect to the maximum emergency rating. The EHWG reached a consensus that there is no need to consider emergency ratings if it can be shown that the relative frequency of a bird ingestion event when using an emergency engine rating is less than 1E–8. Since part 33 does not define emergency ratings for turbofan engines, and the EHWG did not recommend that the FAA add that language, this proposal would not result in harmonizing part 33 with JAR-E in this regard.

Critical ingestion parameter tolerances were reviewed, and supporting arguments were made to justify the reasonableness of using a plus or minus lo-percent tolerance for variations within the test parameters. The application of this tolerance was discussed in the context of setting the engine speed and thrust parameters to test day takeoff conditions as described within this proposed rule. In contrast, the bird weight is controlled to "no less than" the weight specified within this proposed rule. The expectations of achieving the bird aim points and impact speed within plus or minus 10-percent or its equivalent regarding aim point was compared against the general collective test experience. A sensitivity analysis was conducted to evaluate the expected affect on thrust or power, should there be first stage blade damage, for variations in the following test parameters up to lo-percent: engine speed, bird speed, and target location. In general, these tolerances resulted in damage variations which produced approximately a 5-percent affect on thrust or power.

The EHWG determined that the current requirements of § 33.75 and JAR-E5 10 are not exactly the same, and, therefore, are not fully harmonized. The requirement of § 33.75 is restated in the proposed § 33.76 compliance criteria for the proposed medium and large bird ingestion tests. The bird ingestion requirements proposed by the JAA (Notice of Proposed Amendment (NPA–E-20)) includes a reference to JAR-E 510 for compliance criteria. However, the JAA compliance criteria is not the same as contained in this proposed rule. The FAA recognizes that full harmonization of § 33.75 and JAR-E 5 10 is still desirable, and will address this issue in future propulsion harmonization activities.

Disposition of Minority Position (as Stated in the NPA for the JAR on This Subject)

The JAA has expressed disagreement with a portion of this proposal, and is quoted as follows:

The JAA expressed a dissenting opinion by requiring the new rules to include consideration of the threat which is created by flocking birds larger than 2.5 lb. The JAA proposed, in the draft new rules, the imposition of an additional requirement for each engine having an inlet area of 2 100 square-inches or more. The applicant would be required to establish that when the fan assembly of such an engine is subjected to the ingestion of a single bird weighing at least 4 lb., under the same ingestion conditions as prescribed for the 6 lb. or 8 lb. bird ingestion test, the fan assembly retains sufficient integrity to demonstrate a total imbalance level less than 12 percent of the imbalance level corresponding to the loss of one complete fan blade airfoil.

The JAA ***Rationale***

The stated aims of the draft new rules include reducing the risk of a dual engine power loss, the improvement goal being approximately 1E–8 or better per aircraft departure, and substantiation of that goal. The preamble also states that "unless the rule addresses the actual in-service bird threat, there can be no assurance that future designs would continue to exhibit acceptable capability". Allowing fan blades to be shown, during certification, as being less capable to withstand some sizes of birds than current in-service designs is not compatible with those stated aims.

The draft new rules (without the addition proposed by JAA) retain the same acceptance criteria for single large bird ingestion standard as in the existing rules. Extensive damage leading either to an immediate shutdown or necessitating a shutdown after 15 seconds is permitted, the only limit to the severity of the damage to the fan being safe containment, safe loads and no fire. However, in practice there are very good reasons for the manufacturers to establish that, with respect to containment, loads, fire, etc., the damage is not more severe than occurs with a full fan blade release. That practice is recognized in the draft new rules by a provision for waiving a full engine test demonstration of compliance with the large bird ingestion standard if it can be demonstrated that compliance with the requirements for containment of a full fan blade is a more severe demonstration.

Thus, because the minimum design allowed by the draft new rules is actually set primarily by the blade containment requirements, the large bird is allowed to cause extensive damage equivalent to that which results from the release of one entire fan blade. The increase of the weight of the large bird in the draft new rules, from 4 lb. to 6 lb. or 8 lb., will not improve the safety level if engines are designed to the minimum allowed by those new rules because it is a lower minimum that was demonstrated during certification of many, possibly most, of the current in-service engines. Further, it does not automatically follow that designing For a "safe" shutdown with a 6 lb. or 8 lb. bird results in a higher safety level than designing for a "safe" shutdown with a 4 lb. bird.

The certification tests on most of the types of large engines currently in service demonstrated that the 4 lb. bird certification ingestion test did not result in extensive damage to their fan blades. Therefore, the service experience which is the basis for the aims of the draft new rules is derived mainly from engines which were better during certification than required by the existing rules and better than can be allowed under the draft new rules without the JAA proposed addition.

The draft new rules require the large engines to retain a run-on and a 75 percent thrust capability when subjected to a multiple 2.5 lb. bird ingestion test but, as mentioned previously, the 6 lb. or 8 lb. bird ingestion is allowed to result in such extensive fan damage as to necessitate an immediate shutdown. In this case no information would then be available on the behavior of the fan in the event of a 4 lb. bird ingestion because the draft new rules do not address either medium (flocking) birds heavier than 2.5 lb. or large birds lighter than 6 lb. or 8 lb. The ingestion of a 4 lb. bird could, with some fan designs, also result in an immediate unavoidable engine shutdown.

There is already an example of a new engine which complies with the draft new rules for 2.5 lb. and 8 lb. bird ingestion's but the 8 lb. bird was shown to cause extensive damage commensurate with an immediate unavoidable shutdown. It would not have been possible, from only that damage, to make any reasonable assessment of what damage would have resulted from a 4 lb. large bird certification test. Economic pressure could lead to an increased use of fan blades which are designed to the minimum allowed by the draft new rules because it provides an opportunity to reduce the weight of the fan blades, disc and containment ring.

Allowing new fan designs to be less capable than current in-service designs to withstand the ingestion of a 4 lb. bird would not be a concern if the multi-engine ingestion threat did not include birds weighing up to, and more than, 4 lb. However, the service experience supporting the draft new rules shows that the multiple engine ingestion rate for birds larger than 2.5 lb. is greater than 1E–7. With current in-service engines these events have resulted in a marginally acceptable risk of multi-engine shutdown. If no certification data is available to show that new designs are equal to, or better than, current designs at withstanding those birds, it must be assumed that such encounters will result in unavoidable multi-engine shutdowns at a rate of roughly 1E–7 which is in excess of the declared aim of 1E–8. The JAA proposed additional requirement is intended to provide such certification data.

All parties involved in the development of the draft new rules recognize that flocking birds larger than 2.5 lb. may be encountered and the JAA does not disagree totally with the position that mitigation of this risk to 1E–8 or better per airplane departure cannot be economically provided entirely by available engine technology. However, the JAA believes that future engine fan technology must not be allowed to be less capable at mitigating that risk than current in-service engines.

Consequently the JAA concluded that the draft new rules are not achieving the stated aims by an amount that is more than necessary and not ensuring an achievable retention or improvement to the safety level by not ensuring that new fan designs are equal to, or better than, current designs at retaining their integrity when subjected to the ingestion of a 4 lb. bird under the conditions applicable to large bird ingestion requirements. The additional 4 lb. bird consideration proposed by JAA is intended to do no more than to provide some assurance of parity with current in-service fan designs, it is not intended to ensure a full run-on capability after the ingestion of a 4 lb. bird.

The FAA disagrees. The JAA position statement contains two major concerns: (1) That flocking birds larger than 2.5 lb. are a significant enough threat to require an evaluation for run-on capability; and (2) that this proposed rule may allow a lesser capable engine than those certified to the current rule with respect to medium flocking and single large bird ingestion.

With respect to JAA's first major concern, the FAA believes this proposed rule adequately addresses the flocking bird threat within the stated goal of this proposed rulemaking. That improvement goal is to reduce the risk of a dual engine power or thrust loss greater than 50-percent from current in-service rates to approximately 1E–8 or better per aircraft departure.

The worldwide bird ingestion threat database used for the medium and large engine portion of this proposed rulemaking includes substantial data from 1970 through 1995 and encompasses approximately 85-million aircraft flights. The database includes data for engine models with fan inlet diameters from 60 to 100 inches. This database shows the rate of multi-engine ingestions of birds larger than 2.5 lb. to be approximately 1E–7 per aircraft departure. The probability of a dual engine shutdown is predicted to be approximately 1 E-8 per aircraft departure. This probability is based on the observed multi-engine ingestion rate and demonstrated rate of engine shutdown for ingestion of birds in this size range. These rates and probabilities are for engines certified to the current 1.5 lb. medium flocking and 4 lb. single large bird standards, which are less severe than this proposed rule.

The JAA position statement notes that the dual engine power loss and shutdown rate is marginally acceptable today. This proposed rule requires 2.5 lb. medium flocking birds and 6 to 8 lb. large single birds, depending on inlet size, both of which are more severe demonstrations, and which the FAA believes can only improve the overall worldwide fleet bird ingestion capability. This conclusion is also supported by the additional run-on evaluation requirements for the proposed medium bird test. Therefore, the FAA disagrees that additional run-on evaluation requirements for flocking birds larger than 2.5 lb. is necessary.

With respect to the JAA's second major concern for ingestion of medium flocking birds, the current marginally acceptable dual engine power loss rate relates primarily to engines certified to a 1.5 lb. bird ingestion requirement with 5 minutes of run-on. This proposed rule is for a 2.5 lb. bird with a 20 minute run-on evaluation requirement. This proposed rule represents a more severe design and test requirement than for engines certified to the current rule and should yield a more capable engine, not a less capable one. This requirement is supported by a test that is run to worst case conditions of fan speed, target location, number of birds, and new run-on evaluation requirements. The original review of historical data used in the development of this proposed rule showed that ingestion of single large birds greater than 2.5 lb. resulted in a significant engine power loss about 50-percent of the time, which was mostly due to mechanical damage to the fan. It is difficult to see how these earlier certified engines could have a greater ingestion capability than that demonstrated by a minimum engine that passes both the proposed 2.5 lb. medium flocking run-on and 6 to 8 lb. single large bird safe shutdown tests.

With respect to single large bird ingestion, the current marginally acceptable dual engine power loss rate relates primarily to engines certified to a 4 lb. single large bird safe shutdown requirement. With identical test criteria, an engine passing the proposed test will be at least as capable of a large bird safe shutdown as a current engine. Engine models that are tested using the proposed certification standards would have greater axial loads and greater local stresses on the impacted blades than for the 4 lb. requirement. Therefore, the blades must have greater capability with respect to a safe shutdown criteria. The FAA does not believe the proposed large bird ingestion criteria allows sufficient latitude such that an engine can pass the proposed 6 to 8 lb. test but not the current 4 lb. test. The proposal does not alter the current objective of a safe shutdown after a large bird ingestion.

The JAA also states that economic pressures could reduce the margin above the stated compliance criteria that engines may be designed for, and therefore result in less costly and less capable new designs of reduced margin when compared to engines currently in service. The FAA does not believe it is necessary to consider the margin above the certification standard with which any particular engine model demonstrates compliance, and that discussion of economic pressure has no place in objective evaluations of safety. The purpose of this proposed rule is to establish minimum certification requirements below which it is considered unsafe. Every engine meeting these proposed minimum requirements will be considered safe; either the regulatory criteria is appropriate, or it is not. Margin is not an issue when discussing properly chosen criteria. The FAA considers this proposed criteria as appropriate and, therefore, demonstrated margin above that criteria is not necessary. With respect to engines certified to the current 4 lb. single large bird ingestion safe shutdown test standard, some fan designs have exhibited blade fragmentation during the test while others have not. It is incorrect, however, to infer continued run-on capability simply from lack of fan blade fragmentation during the 15-second “hands-off” period of the large bird ingestion test. Secondary damage and operability affects of continued high power operation with mechanical or aerodynamic unbalance, or both, would have to be taken into consideration.

It is also true that currently certified designs which have experienced fan blade fragmentation in large bird ingestion tests have accumulated well over 50-million hours in revenue service with a satisfactory bird ingestion record. The fact that these engines continue to operate and produce greater than 50-percent thrust in a significant percentage of revenue service large bird ingestion events, may well be attributable more to the combination of ingestion conditions being less severe than the certification test, rather than to the robustness of the fan design. The FAA expects this same mixed result will continue to occur in the single large bird ingestion certification test. In addition, such mixed results relative to fan blade fragmentation are not significant relative to this proposed rulemaking’s intent of improving the world fleet rate of dual engine power loss.

The FAA disagrees with the JAA statement that this proposed rule has a lower design minimum than the current rule. The FAA believes that this proposed rule significantly increases the certification standards for medium and large bird ingestion by increased severity of bird size, run-on, and target location. The test criteria of the current rule is less severe than that specified under this proposed rule, therefore, it cannot be described as providing a "greater margin" when compared to a marginally compliant engine under this proposed rule. Furthermore, no evidence has been offered to demonstrate that engines certified under the current rule would always have a margin for run-on following the ingestion of a 4 lb. flocking bird. Thus, the arguments of current versus proposed criteria are considered subjective and unproven as indicators of future performance in service.

Consequently, for the reasons stated above, the FAA has concluded that evaluation of run-on capability for birds or ingestions larger than 2.5 lb. is not necessary to meet this proposed rulemaking objective, and therefore the JAA proposal does not need to be incorporated into this proposed rule.

General Discussion of the Proposals

Sections 23.903 (a) (2) and 25.903 (a) (2)

The proposal revises parts 23 and 25 requirements associated with foreign object ingestion into turbine engines to be consistent with the proposed part 33 requirements.

Section 33.76

The proposed new (§ 33.76 would contain the new bird ingestion requirements. This proposal was developed by the engine harmonization working group, and contains substantial common language that will be reflected both in part 33 and JAR-E. Also, the proposed new section adopts the approximate metric equivalents for certain test parameters to further commonality between part 33 and JAR–E.

Section 33.77

The proposed revisions to (§ 33.77 would remove the bird ingestion standards now specified in (§ 33.77(a) and (§ 33.77(b). Paragraphs (a) and (b) would be held in reserve. Paragraphs (d) and (e) would be revised to eliminate any reference to paragraphs (a) and (b). The table in paragraph (e) would be revised to remove bird ingestion standards.

Paperwork Reduction Act

As there are no requirements for information collection associated with this proposed rule, no analysis of paperwork requirements is required under the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 *et seq.).*

Regulatory Evaluation Summary

Four principal requirements pertain to the economic impacts of changes to the Federal regulations. First, Executive Order 12866 directs Federal agencies to promulgate new regulations or modify existing regulations after consideration of the expected benefits to society and the expected costs. The order also requires federal agencies to assess whether a proposed rule is considered a "significant regulatory action." Second, the Regulatory Flexibility Act of 1980 requires agencies to analyze the economic impact of regulatory changes on small entities. Third, the Office of Management and Budget directs agencies to assess the effect of regulatory changes on international trade. Finally, Public Law 104-4 requires federal agencies to assess the impact of any federal mandates on state, local, tribal governments, and the private sector.

In conducting these analyses, the FAA has determined that this proposed rule would generate cost-savings that would exceed any costs, and is not "significant" as defined under section 3 (f) of Executive Order 12866 and DOT policies and procedures (44 FR 11034, February 26, 1979). In addition, under the Regulatory Flexibility Determination, the FAA certifies that this proposal would not have a significant impact on a substantial number of small entities. Furthermore, this proposal would not impose restraints on international trade. Finally, the FAA has determined that the proposal would not impose a federal mandate on state, local, or tribal governments, or the private sector of $100 million per year. These analyses, available in the docket, are summarized below.

Cost and Benefits

The FAA estimates that the proposed rule would add $250,000 to $500,000 to each new engine model's certification costs, depending on engine inlet area. These costs would be incurred primarily in two areas. First, additional analysis required to verify the affects of a large bird impact on the front of the engine could necessitate a component test costing $250,000. Second, the proposed rule would require additional analysis or testing on the full fan assembly for engines with inlet areas greater than 2,092 square-inches. Such testing would cost an additional approximately $250,000 for those engines.

In addition, the revised bird test weights could necessitate strengthening fan components, thereby affecting fan performance. The FAA estimates that reduced fan efficiency would result in a 0.2-percent increase in fuel consumption. On average, this would increase annual fuel costs by $4,770 per airplane.

Benefits associated with the proposed rule include: (1) benefits from averted fatalities and injuries, (2) benefits from averted property damage (primarily hull losses), and (3) benefits associated with reduced maintenance and repair costs. Based on historical accident information, the FAA estimates that the expected annual per-airplane benefit from averted airplane damage or loss is approximately $657. The expected annual per-airplane benefit from averted fatalities and injuries is $654 and $75, respectively.

The estimated value of maintenance/ repair savings associated with the proposed rule is based on an analysis of the relationship between bird ingestion weight and the probability of damage. The FAA estimates that, on average, the proposed rule would save operators approximately $4,654 per airplane per year.

To compare the costs and benefits of the proposed rule, the evaluation considers a hypothetical representative engine certification. The engines are assumed to be installed on a notional twin-engine jet transport with a seating capacity of 161 (the average seating capacity of jet transports in commercial service in 1996). In addition, this analysis assumes that: (1) the discount rate is 7-percent, (2) incremental engine certification costs equal $250,000 in year 0 and $250,000 in year 1, (3) production of engines commences in year 2, (4) engines are installed in aircraft and enter service beginning in year 3, (5) each engine has a 15-year service life, and (6) 24 engines are produced per year for 10 years so that there are 240 total engines and 120 airplanes per certification. Under these assumptions, the expected discounted benefits of the proposed rule would exceed discounted costs by a factor of 1.11 ($4,333,000 to $3,906,000).

International Trade Impact Analysis

The proposed rule would have little or no affect on international trade for either U.S. firms marketing turbine engines in foreign markets or foreign firms marketing turbine engines in the U.S.

Regulatory Flexibility Determination

The Regulatory Flexibility Act of 1980 establishes "as a principle of regulatory issuance that agencies shall endeavor, consistent with the objectives of the rule and of applicable statutes, to fit regulatory and informational requirements to the scale of the businesses, organizations, and governmental jurisdictions subject to regulation." To achieve that principle, the Act requires agencies to solicit and consider flexible regulatory proposals and to explain the rationale for their actions. The Act covers a wide range of small entities, including small businesses, not-for-profit organizations, and small governmental jurisdictions.

Agencies must perform a preliminary analysis of all proposed rules to determine whether the rule will have a significant economic impact on a substantial number of small entities; if the determination is that it will, the agency must prepare an initial regulatory flexibility analysis (RFA) .

However, if after a preliminary analysis for a proposed or final rule, an agency determines that a rule is not expected to have a significant economic impact on a substantial number of small entities, Section 605(b) of the Act provides that the head of the agency may so certify. The certification must include a statement providing the factual basis for this determination, and the reasoning should be clear.

The FAA conducted the required preliminary analysis of this proposal and determined that it will not have a significant economic impact on a substantial number of small entities. The following statement summarizes the basis for this determination. The proposed rule would apply only to newly designed turbine aircraft engines certificated in the future. Each new engine certification could affect two types of small entities.

First, the manufacturer would be required to perform additional analysis or testing to demonstrate that the proposed new bird ingestion requirements are met. There are currently nine turbine aircraft engine manufacturers with headquarters in the U.S. (this count includes subsidiaries of foreign entities and consortiums of domestic and/or foreign entities). Information available to the FAA at this time indicates that only one of these—a U.S. manufacturer of small turbine engines-has less than 1,500 employees and, therefore, qualifies as a small business under guidelines issued by the Small Business Administration.

It is difficult to estimate total costs to this single manufacturer because these costs are a function of the number of engines certificated. The manufacturer is not expected to conduct bird ingestion testing in the foreseeable future. In view of this uncertainty, this analysis focuses on per engine costs for both manufacturers and operators. The proposed rule is estimated to add about $250,000 for a small engine type as currently manufactured by the single small entity (these are one time costs per certification). The FAA estimates that the proposed rule would impose no manufacturing costs. In light of the fact that there is only one known small business manufacturing turbine aircraft engines, and that manufacturer is not expected to be affected by the proposed rule in the foreseeable future, this analysis will assume that manufacturing costs imposed by this proposed rule will be passed on to operators who purchase the new engines and analyze these costs on small operators.

Aircraft operators would incur slightly higher engine prices, plus pay increased operating or fuel costs due to the small decrease in engine efficiency described in the full regulatory evaluation. According to FAA data, there are about 3,000 air carriers having less than 1,500 employees—approximately 100 air carriers operating under part 12 1 (or both part 12 1 and part 135), and 2.900 air carriers operating under part 135.

Assuming conservatively that: (1) All incremental certification costs are passed on to the buyer/operator, (2) the manufacturer recovers incremental certification costs by applying a uniform price increase to 240 engines produced during a lo-year production run, and (3) that the discount rate is 7-percent; then the FAA estimates that average engine prices will increase by approximately $3,070 per larger engine and $1,587 per smaller engine. When these costs are amortized over the 15-year life of an engine (again, assuming a 7-percent discount rate), the incremental annualized cost per engine is approximately $3 15 and $163 for larger and smaller engines, respectively. Therefore, assuming a typical airplane has two engines, the incremental annualized cost for a large airplane is approximately $630 and the incremental annualized cost for a smaller airplane is approximately $326.

For larger engines, the rule will also increase annual airplane operating costs as a result of the proposed medium bird ingestion requirements (these requirements would have a negligible affect on smaller engines). On average, annual operating costs per large airplane, therefore, would increase by approximately $4,770. However, the reduction in average annualized maintenance costs associated with the more damage resistant engines that would be developed as a result of this proposed rule would almost completely offset incremental operating costs. These reduced maintenance costs are described more fully in the full regulatory evaluation.

Total annualized costs for operators of larger and smaller airplanes would therefore be approximately $630 and $326 per airplane, respectively. Consequently, the FAA makes an initial certification that the proposed rule would not have a significant economic impact on a substantial number of small entities.

Federalism Implications

The regulations proposed herein would not have substantial direct affects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government; and would not impose substantial direct compliance costs on States or local governments. Therefore, in accordance with Executive Order 12612, it is determined that this proposal would not have sufficient federalism implications to require consultation with representatives of affected States and local governments.

In addition, the regulations proposed herein would not significantly or uniquely affect the communities of the Indian tribal governments and would not impose substantial direct compliance costs on such communities. Therefore, in accordance with Executive Order 13084, it is determined that this proposal would not require consultation with representatives of affected Indian tribal governments.

Environmental Assessment

FAA Order 1050.1D defines FAA actions that may be categorically excluded from preparation of a National Environmental Policy Act (NEPA) environmental assessment (EA) or environmental impact statement (EIS). In accordance with FAA Order 1050. 1D, appendix 4, paragraph 4 (j) , regulations, standards, and exemptions (excluding those, which if implemented may cause a significant impact on the human environment) qualify for a categorical exclusion. The FAA has determined that this rule qualifies for a categorical exclusion because no significant impacts to the environment are expected to result from its finalization or implementation. In accordance with FAA Order 1050.1D, paragraph 32, the FAA has determined that there are no extraordinary circumstances warranting preparation of an environmental assessment for this proposed rule.

List of Subjects in 14 CFR Parts 23, 25 and 33

Air transportation, Aircraft, Aviation safety, Safety.

The Proposed Amendment

In consideration of the foregoing, the Federal Aviation Administration proposes to amend parts 23, 25 and 33 of Title 14, Code of Federal Regulations as follows:

PART 23-AIRWORTHINESS STANDARDS: NORMAL, UTILITY, ACROBATIC, AND COMMUTER CATEGORY AIRPLANES

1. The authority citation for part 23 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701, 44702, 44704.

2. Section 23.903 is amended by revising paragraph (a)(2) to read as follows:

§ 23.903 Engines.

(a) * * *

(2) Each turbine engine and its installation must comply with one of the following:

(i) Sections 33.76, 33.77 and 33.78 of this chapter in effect on (effective date of final rule), or as subsequently amended; or

(ii) Sections 33.77 and 33.78 of this chapter in effect on April 30, 1998, or as subsequently amended before (effective date of final rule) ; or

(iii) Section 33.77 of this chapter in effect on October 31, 1974, or as subsequently amended before April 30, 1998, unless that engine's foreign object ingestion service history has resulted in an unsafe condition; or

(iv) Be shown to have a foreign object ingestion service history in similar installation locations which has not resulted in any unsafe condition.

* * * * *

PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

3. The authority citation for part 25 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701, 44702, 44704.

4. Section 25.903 is amended by revising paragraph (a) (2) to read as follows:

§ 25.903 Engines.

(a) * * *

(2) Each turbine engine must comply with one of the following:

(i) Sections 33.76, 33.77 and 33.78 of this chapter in effect on (effective date of final rule), or as subsequently amended: or

(ii) Sections 33.77 and 33.78 of this chapter in effect on April 30, 1998, or as subsequently amended before (effective date of final rule); or

(iii) Comply with § 33.77 of this chapter in effect on October 31, 1974, or as subsequently amended prior to April 30, 1998, unless that engine's foreign object ingestion service history has resulted in an unsafe condition; or

(iv) Be shown to have a foreign object ingestion service history in similar installation locations which has not resulted in any unsafe condition.

* * * * *

PART 33-AIRWORTHINESS STANDARDS: AIRCRAFT ENGINES

5. The authority citation for part 33 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701, 44702, 44704.

6. Section 33.76 is added to read as follows:

§ 33.76 Bird ingestion.

(a) ***General.*** Compliance with paragraphs (b) and (c) of this section shall be in accordance with the following:

(1) All ingestion tests shall be conducted with the engine stabilized at no less than loo-percent takeoff power or thrust for test day ambient conditions prior to the ingestion. In addition, the demonstration of compliance must account for engine operation at sea level takeoff conditions on the hottest day that a minimum engine can achieve maximum rated takeoff thrust or power.

(2) The ***engine inlet area*** as used in this section to determine the bird quantity and weights will be established by the applicant and identified as a limitation on the inlet throat area in the installation instructions required under § 33.5.

(3) The impact to the front of the engine from the single large bird and the single largest medium bird which can enter the inlet must be evaluated. It must be shown that the associated components when struck under the conditions prescribed in paragraphs (b) or (c) of this section, as applicable, will not affect the engine to the extent that it cannot comply with the requirements of paragraphs (b) (3) and (c) (6) of this section.

(4) For an engine that incorporates an inlet protection device, compliance with this section shall be established with the device functioning. The engine approval will be endorsed to show that compliance with the requirements has been established with the device functioning.

(5) Objects that are accepted by the Administrator may be substituted for birds when conducting the bird ingestion tests required by paragraphs (b) and (c) of this section.

(6) If compliance with the requirements of this section is not established, the engine type certification documentation will show that the engine shall be limited to aircraft installations in which it is shown that a bird cannot strike the engine, or be ingested into the engine, or adversely restrict airflow into the engine.

(b) ***Large birds.*** Compliance with the large bird ingestion requirements shall be in accordance with the following:

(1) The large bird ingestion test shall be conducted using one bird of a weight determined from Table 1 aimed at the most critical exposed location on the first stage rotor blades and ingested at a bird speed of 200 knots for engines to be installed on airplanes, or the maximum airspeed for normal rotorcraft flight operations for engines to be installed on rotorcraft.

(2) Power lever movement is not permitted within 15 seconds following ingestion of the large bird.

(3) Ingestion of a single large bird tested under the conditions prescribed in this section may not cause the engine to:

(i) Catch fire;

(ii) Release hazardous fragments through the engine casing;

(iii) Generate loads greater than those ultimate loads specified under § 33.23(a); or

(iv) Lose the ability to be shut down.

(4) Compliance with the large bird ingestion test requirements of this paragraph may be waived if it can be demonstrated that the containment requirements of § 33.94 (a) constitute a more severe demonstration than the requirements of this paragraph.

TABLE 1.- LARGE BIRD WEIGHT REQUIREMENTS

Engine inlet area (A) square-meters (square-inches)	Bird weight kg. (lb.)
1.35(2,092)>A . . .	1.85 (4.07) minimum, unless a smaller bird is determined to be a more severe demonstration.
1.35 (2,092)≤A<3.90 (6,045).	2.75 (6.05).
3.90 (6,045)≤A ...	3.65 (8.03).

(c) Small and medium birds. Compliance with the small and medium bird ingestion requirements shall be in accordance with the following:

(1) Analysis or component test, or both, acceptable to the Administrator, shall be conducted to determine the critical ingestion parameters affecting power loss and damage. Critical ingestion parameters shall include, but are not limited to, the affects of bird speed, critical target location, and first stage rotor speed. The critical bird ingestion speed should reflect the most critical condition within the range of airspeeds used for normal flight operations up to 1,500 feet above ground level, but not less than V_1 minimum for airplanes.

(2) Medium bird engine tests shall be conducted so as to simulate a flock encounter, and will use the bird weights and quantities specified in Table 2. When only one bird is specified, that bird will be aimed at the engine core primary flow path; the other critical locations on the engine face area must be addressed, as necessary, by appropriate tests or analysis, or both. When two or more birds are specified in Table 2, the largest of those birds must be aimed at the engine core primary flow path, and a second bird must be aimed at the most critical exposed location on the first stage rotor blades. Any remaining birds must be evenly distributed over the engine face area.

(3) In addition, except for rotorcraft engines, it must also be substantiated by appropriate tests or analysis or both, that when the full fan assembly is subjected to the ingestion of the quantity and weights of birds from Table 3, aimed at the fan assembly's most critical location outboard of the primary core flowpath, and in accordance with the applicable test conditions of this paragraph, that the engine can comply with the acceptance criteria of this paragraph.

(4) A small bird ingestion test is not required if the prescribed number of medium birds pass into the engine rotor blades during the medium bird test.

(5) Small bird ingestion tests shall be conducted so as to simulate a flock encounter using one 85 gram (0.187 lb.) bird for each 0.032 square-meter (49.6 square-inches) of inlet area, or fraction thereof, up to a maximum of 16 birds. The birds will be aimed so as to account for any critical exposed locations on the first stage rotor blades, with any remaining birds evenly distributed over the engine face area.

(6) Ingestion of small and medium birds tested under the conditions prescribed in this paragraph may not cause any of the following:

(i) More than a sustained 25-percent power or thrust loss;

(ii) The engine to be shut down during the required run-on demonstration prescribed in paragraphs (c) (7) or (c) (8) of this section;

(iii) The conditions defined in paragraph (b)(3) of this section.

(iv) Unacceptable deterioration of engine handling characteristics.

(7) Except for rotorcraft engines, the following test schedule shall be used:

(i) Ingestion so as to simulate a flock encounter, with approximately 1 second elapsed time from the moment of the first bird ingestion to the last.

(ii) Followed by 2 minutes without power lever movement after the ingestion.

(iii) Followed by 3 minutes at 75 percent of the test condition.

(iv) Followed by 6 minutes at 60 percent of the test condition.

(v) Followed by 6 minutes at 40 percent of the test condition.

(vi) Followed by 1 minute at approach idle.

(vii) Followed by 2 minutes at 75 percent of the test condition.

(viii) Followed by stabilizing at idle and engine shut down. The durations specified are times at the defined conditions with the power lever being moved between each condition in less than 10 seconds.

(8) For rotorcraft engines, the following test schedule shall be used:

(i) Ingestion so as to simulate a flock encounter within approximately 1 second elapsed time between the first ingestion and the last.

(ii) Followed by 3 minutes at 75 percent of the test condition.

(iii) Followed by 90 seconds at descent flight idle.

(iv) Followed by 30 seconds at 75 percent of the test condition.

(v) Followed by stabilizing at idle and engine shut down. The duration specified are times at the defined conditions with the power being changed between each condition in less than 10 seconds.

(9) Engines intended for use in multi-engine rotorcraft are not required to comply with the medium bird ingestion portion of this section, providing that the appropriate type certificate documentation is so endorsed.

(10) If any engine operating limit(s) is exceeded during the initial 2 minutes without power lever movement, as provided by paragraph (c) (7) (ii) of this section, then it shall be established that the limit exceedence will not result in an unsafe condition.

TABLE 2.-MEDIUM FLOCKING BIRD WEIGHT AND QUANTITY REQUIREMENTS

Engine inlet area (A) square-meters (square-inches)	Bird quantity	Bird weight kg. (lb.)
0.05 (77.5)> A	None	
.05 (77.5)≤ A < 0.10 (155)	1	0.35 (0.77).
0.10 (155)≤ A < 0.20 (310)	1	0.45 (0.99).
0.20 (310)≤ A < 0.40 (620)	2	0.45 (0.99).
0.40 (620)≤ A < 0.60 (930)	2	0.70 (1.54).
0.60 (930)≤ A < 1.00 (1,550)	3	0.70 (1.54).
1.00 (1,550)≤ A < 1.35 (2,092)	4	0.70 (1.54).
1.35 (2,092)≤ A < 1.70 (2,635)	1	1.15 (2.53).
	Plus 3	0.70 (1.54).
1.70 (2,635)≤ A < 2.10 (3,255)	1	1.15 (2.53).
	Plus 4	0.70 (1.54).
2.10 (3,255)≤ A < 2.50 (3,875)	1	1.15 (2.53).
	Plus 5	0.70 (1.54).
2.50 (3,875)≤ A < 3.90 (6045)	1	1.15 (2.53)
	Plus 6	0.70 (1.54).
3.90 (6045)≤ A < (6975)	3	1.15 (2.53)
4.50 (6975)≤ A	4	1.15 (2.53).

TABLE 3.—ADDITIONAL INTEGRITY ASSESSMENT

Engine inlet area (A) square-meters (square-inches)	Bird quantity	Bird weight kg. (lb.)
1.35 (2,092)> A	None	
1.35 (2,092)≤ A 2.90 (4,495)	1	1.15 (2.53).
2.90 (4,495)≤ A < 3.90 (6,045)	2	1.15 (2.53).
3.90 (6,045)≤ A	1	1.15 (2.53).
	Plus 6	0.70 (1.54).

7. Section 33.77 is amended by removing and reserving paragraphs (a) and (b) and by revising paragraphs (d) (3) and (e) to read as follows:

§ 33.77 Foreign object ingestion.

* * * * *

(d) * * *

(3) The foreign object, or objects, stopped by the protective device will not obstruct the flow of induction air into the engine with a resultant sustained reduction in power or thrust greater than those values required by paragraph (c) of this section.

(e) Compliance with paragraph (c) of this section must be shown by engine test under the following ingestion conditions:

Foreign object	Test quantity	Speed of foreign object	Engine operation	Ingestion
Ice	Maximum accumulation on a typical inlet cowl and engine face resulting from a 2-minute delay in actuating anti-icing system, or a slab of ice which is comparable in weight or thickness for that size engine.	Sucked in	Maximum cruise	To simulate a continuous maximum icing encounter at 25 degrees Fahrenheit.

Issued in Washington, DC, on December 2, 1998.

Elizabeth Erickson,

Director, Aircraft Certification Service.

[FR Doc. 98-32734 Filed 12-10-98; 8:45 am]

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[4910-13]

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Parts 23, 25 and 33

[Docket No. FM-1998-4815; Notice No. 98-18]

~~[Docket No. , Notice No.]~~ SP 12/4/98

RIN 2120-AF34

Airworthiness Standards; Bird Ingestion

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of proposed rulemaking (NPRM).

SUMMARY: This document proposes to amend the FAA type certification standards for aircraft turbine engines with regard to bird ingestion. The proposed standards reflect recent analyses defining the actual bird threat encountered in service by turbine engines, and would harmonize the FAA bird ingestion standards with those being drafted by the Joint Aviation Authorities (JAA). The proposed changes would establish nearly uniform bird ingestion standards for aircraft turbine engines certified by the United States under FAA standards and by the JAA countries under JAA standards, thereby simplifying airworthiness approvals for import and export.

DATE: Comments to be submitted on or before [Insert date 90 days after the date of publication in the Federal Register].

Pub. 12/11/98
Part V
Comments end. 3/11/99

FP 12/4/98

ADDRESSES: Comments on this document should be mailed, in triplicate to: Federal Aviation Administration, Office of the Chief Counsel, Attention: Rules Docket (AGC-200), Docket No. FAA-1998-4815, Room 9 15G, 800 Independence Avenue, SW., Washington, DC 2059 1. Comments submitted must be marked: "Docket No. FAA-1998-4815." Comments may also be sent electronically to the following intemet address: 9-NPRM-CMTS@faa.dot.gov. Comments may be examined in Room 9 15G on weekdays, except Federal holidays, between 8:30 a.m. and 5:00 p.m.

FOR FURTHER INFORMATION CONTACT: Marc Bouthillier, Engine and Propeller Standards Staff, ANE- 110, Engine and Propeller Directorate, Aircraft Certification Service, FAA, New England Region, 12 New England Executive Park, Burlington, Massachusetts 01803-5299; telephone (78 1) 23 8-7 120; fax (781) 238-7199.

SUPPLEMENTARY INFORMATION:

Comments Invited

Interested persons are invited to participate in the making of the proposed rule by submitting such written data, views, or arguments as they may desire. Comments relating to the environmental, energy, federalism, or economic impact that might result from adopting the proposals in this notice are also invited. Substantive comments should be accompanied by cost estimates. Comments must identify the regulatory docket number and be submitted in triplicate to the Rules Docket address specified above.

All comments received, as well as report summarizing each substantive public contact with FAA personnel on this proposed rulemaking, will be filed in the docket. The docket is available for public inspection before and after the comment closing date.

All comments received on or before the closing date will be considered by the Administrator before taking action on this proposed rulemaking. Late-filed comments will be considered to the extent practicable. The proposals contained in this notice may be changed in light of comments received.

Comrnenters wishing the FAA to acknowledge receipt of their comments submitted in response to this notice must include a pre-addressed, stamped postcard with those comments on which the following statement is made: "Comments to Docket No. ." The postcard will be date stamped and mailed to the commenter.

Availability of NPRM's

An electronic copy of this document may be downloaded using a modem and suitable communications software from the FAA regulations section of the Fedworld electronic bulletin board service (telephone: 703-321-3339), the Federal Register's electronic bulletin board service (telephone: 202-512-1661), or the FAA's Aviation Rulemaking Advisory Committee Bulletin Board service (800)-322-2722 or (202)-267-5948.

Internet users may reach the FAA's webpage at http://www.faa.gov/avr/arm/nprm/nprm.htm or the Government Printing Office's webpage at http://www.access.gpo.gov/su_docs/aces/aces140.html for access to recently published rulemaking documents.

Any person may obtain a copy of this NPRM by submitting a request to the Federal Aviation Administration, Office of Rulemaking, ARM-l, 800 Independence Avenue, SW., Washington, DC 20591, or by calling (202) 267-9680. Communications must identify the docket number of this NPRM.

Persons interested in being placed on the mailing list for future NPRM's should request, from the above office, a copy of Advisory Circular No. 11-2A, Notice of Proposed Rulemaking Distribution System, which describes the application procedure.

Background

Statement of the Problem

In 1976, the National Transportation Safety Board (NTSB), in response to an accident involving a wide-bodied aircraft that may have experienced multiple bird ingestion into the engines, issued Safety Recommendation A-76-64, recommending that the FAA, "amend 14 CFR 33.77 to increase the maximum number of birds in the various size categories required to be ingested into turbine engines with large inlets." Safety Recommendation A-76-64 also stated, "these increased numbers and sizes should be consistent with the birds ingested during service experience of these engines." In response to the recommendation, the FAA sponsored an industry wide study of the types, sizes, and quantities of birds that had been ingested into aircraft turbine engines of all sizes, and the resulting affects on engine performance. Subsequently, the FAA requested that the Aerospace Industries Association (AIA) analyze the data, and report back to the FAA. Based on the AIA report, the FAA determined the actions to be taken, as well as the disposition of the NTSB safety recommendation A-76-64. The FAA concluded that the regulations contained in § 33.77 should be modified to increase the severity of the bird ingestion testing requirements regarding large, high bypass ratio engines. In addition, the FAA found that it should update the design and testing requirements for all engine sizes to reflect the actual numbers and bird sizes being ingested. This effort was adopted as a part 33 and Joint Aviation Regulations for engines (JAR-E) harmonization project and was selected as an Aviation Rulemaking Advisory Committee (ARAC) project.

Industry Study

The industry study consisted of FAA sponsored contracts which are summarized in FAA report number DOT/FAA/CT-84/13, dated September 1984. The AIA and the Association Europeenne Des Constructeurs De Material Aerospatial (AECMA), initially reviewed the historical bird threat and resulting impact to flight safety for a 20-year period through 1987. The data collected represented a cross-section of large, high bypass turbofan engines in service during that time period. After collection and review of the available data, an analysis was performed to characterize both the threat of bird ingestion (sizes, quantities and occurrence rates) and consequences. The results of this initial data analysis were presented to the FAA in AIA reports dated October 17, 1986, and November 10, 1988. The results of the analysis were compared to the historical design standards and certification bases for the family of engines comprised in the database. As a result of that analysis, the industry study group identified bird encounter threats more severe than were addressed in either engine design practices of the time, or in part 33. Subsequently, additional data was collected and analyzed for small and medium sized turbine engines which were not represented within the initial database. This data is contained within FAA Technical Center reports dated December 1990, December 199 1, and July 1992.

In addition to the industry study and data analysis for large engines, industry also addressed the service experience of the small turbojet and turbofan engine designs. With the rapid expansion of the turbojet and turbofan engine powered business jet fleet in the late 1960’s and early 1970's, a significant number of multiple engine power loss accidents occurred due to flocking bird ingestion. Careful review of these turbojet and turbofan engine events showed that the flight crews had often flown through very large flocks of birds with ingestion of many birds in each engine which resulted in multiple engine flameouts.

At the time, the FAA engaged in a discussion with engine manufacturers, and concluded that mechanical design changes alone would not alleviate the adverse affects of severe inlet blockage caused by massive flocking bird ingestions. The FAA and the manufacturers, then embarked upon a campaign to better inform the aviation community regarding bird hazards and necessary airport controls, and the accident rate due to bird ingestion decreased markedly. Additionally, the FAA amended part 33 effective October 3 1, 1974 (amendment 33-6), to require manufacturers to incorporate significant design improvements to address the typical flocking bird threat. The service experience of business jet engine designs that meet the standards of amendment of 33-6 indicates that resistance to bird ingestion induced damage has greatly improved over earlier service history.

Aviation Rulemaking Advisory Committee (ARAC) Project

The FAA is committed to undertaking and supporting the harmonization of part 33 with JAR-E. In August 1989, as a result of that commitment, the FAA Engine and Propeller Directorate participated in a meeting with the Joint Aviation Authorities (JAA), AIA, and AECMA. The purpose of the meeting was to establish a philosophy, guidelines, and a working relationship regarding the resolution of issues identified as needing to be harmonized, including some where new standards are needed. All parties agreed to work in a partnership to jointly address the harmonization effort task. This partnership was later expanded to include the airworthiness authority of Canada, Transport Canada.

This partnership identified seven items as the most critical to the initial harmonization effort. The proposed bird ingestion standards represent one item on the list of seven, and, therefore, represent a critical harmonization effort.

The bird ingestion standards proposal was selected as an ARAC project, and assigned to the Engine Harmonization Working Group (EHWG) of the Transport Airplane and Engine Issues Group (TAEIG) on December 11, 1992 (57 FR 58840). On April 9, 1997, the TAEIG recommended that the FAA proceed with the proposed rulemaking and associated advisory material even though one working group member disagreed with the proposal. This proposed NPRM reflects the ARAC recommendations on that rulemaking.

The basis for the development of this proposed rule is to (1) minimize the threat to aircraft from the historical bird threat to one or more engines; and (2) substantiate that the engine design provides at least a 1E-8 per aircraft cycle freedom from risk of a hazardous consequence to the aircraft due to the bird ingestion threat. For all bird ingestion threats, a hazardous consequence occurs when the resulting damage to the engine results in an unsafe condition specified in § 33.75; and in the specific case of small and medium birds, where insufficient power is retained to provide engine run-on capability to ensure a safe landing.

Medium bird ingestion criteria for small engines was established consistent with corresponding criteria for medium and large engines, which is freedom from multi-engine power loss events at a rate of 1E-8 per aircraft cycle. These criteria are based on the assumption that current standards for airport certification will be maintained, that the historical environment will not worsen, and that airport operators and pilots will maintain at least their current awareness of the bird ingestion threat.

The development of this proposal recognizes that each engine design must address the bird ingestion threat, without regard to the ingestion capability of previous designs as described in the service history database. Unless the proposal addresses the actual in-service bird ingestion threat, there can be no assurance that future designs would continue to exhibit acceptable capability'.

The results of this data analysis are summarized as follows:

1. Dual engine power loss events with hazardous consequences (flocking birds of all sizes) have occurred at the rate of 3.2E-7 occurrences per aircraft cycle for large high-bypass ratio engines. This finding reflects service data for the 20-year period through 1987.

2. Multiple engine ingestion of flocking birds up to 2.5 lbs. has occurred at the rate of 1E-6 occurrences per aircraft cycle for large high-bypass ratio engines.

3. Single engine power loss events due to ingestion of birds smaller than the current § 33.77 standard has occurred at a rate of 1E-6 or greater per aircraft cycle for all large high-bypass ratio engines.

4. Single engine ingestion of a large bird (4-8 lb. based on inlet area) has occurred at a rate up to 3.1E-6 occurrences per aircraft cycle.

5. Dual engine ingestion of flocking birds up to 1.5 lbs. has occurred at a rate of 1E-8 occurrences per aircraft cycle for small engines.

6. Bird ingestion service difficulty issues relating to engine models not type certificated to the proposed requirements, can safely be addressed by continued airworthiness control programs.

This proposal recognizes the need to design a conservative test, while at the same time being representative of in-service combinations of critical ingestion parameters. Since testing for all possible combinations of events is impractical, a degree of conservatism was called for in a single test demonstration. That conservatism was incorporated into the proposed tests by selecting bird sizes or quantities, or both, among the most severe encountered within the 1E-8 service history, as well as requiring critical test parameters to be at worse case combination (speeds and aim points). It is therefore reasonable to accept a satisfactory test outcome which is conservative with respect to the various combinations of critical test parameters, and their demonstrated rate of occurrence in service.

An example of parametric rule consideration during regulatory tests is the question of multiple bird impacts to the same rotor blade. The likelihood of multiple impacts on one blade is dependent on the number of birds, the number of blades, and the exposed frontal area. The aircraft and engine manufacturers have stated that it is not always possible to achieve a uniform distribution of birds across the complete face of the engine in a single engine test. This situation could result in multiple birds striking the same blade, and may be viewed as unrepresentative and overly conservative based on probabilities appropriate to a random ingestion (averaged over a multiple ingestion event).

With respect to the flocking bird threat, this proposal considers the potential affects on the engine associated with the size and number of birds, and operating conditions of pertinent aircraft. For smaller flocking birds (0.5 to 1.5 lb.), greater quantities of birds may be ingested when compared to quantities associated with larger size flocking birds. The proposed tests would require the applicant to consider both the affects of bird size on the impact loading of the engine components, as well as the quantity ingested with potential multiple target locations being struck on the face of the engine. Additionally, the applicant would have to consider the potential affects of the ingestion and the resultant damage to the front face of the engine, as they affect the engine core and engine's run-on capability.

Analysis of the service record of engines with an inlet surface area larger than 2,000 square-inches over a 20-year period has led to the conclusion that some additional certification standards are required. The proposed standards are intended to reduce the risk of a dual engine power loss from current in-service rates. The improvement goal is approximately 1E-8 or better per aircraft departure. The data analysis has identified specific flocking bird threats up to approximately 8 lb. size (Canada goose). Therefore, it is the intent of this proposed rule to strengthen the engine airworthiness requirements by increasing the medium bird ingestion requirements from 1.5 to 2.5 lb. birds (representing the herring gull threat) and, by increasing the single large bird ingestion requirements, to address bird threats from 4 to 8 lb. (Canada goose). (The term "1E-8" is a standard scientific notation.)

The FAA recognizes that flocking birds larger than those specified in this proposed rule may be encountered. While available engine technology alone may not provide mitigation of this risk to approximately 1E-8 or better per aircraft departure, mitigation of this threat may be provided by compliance with the more severe requirements of this proposal. In addition, the introduction of aircraft that can be operated with up to a 50-percent power loss from each engine (large, twin engine, transport aircraft) and improved airport bird control methods and awareness will further address this very large bird threat. The data summary supporting this conclusion for medium to large high bypass engines (70 to 100 inch inlet diameter except as noted) is as follows:

Multiple engine ingestions of birds greater than 1 .O lb. = **2.1E-6***

Multiple engine ingestions of birds greater than 1.5 lb. = **1.4E-6***

Multiple engine ingestions of birds greater than 2.5 lb. = **1.4E-7****

Multiple engine ingestions of birds greater than 4.0 lb. = **8.8E-8****

Multiple engine ingestions of birds greater than 2.5 lb. = **9.5E-8*****

*Data collection period **1970-** 1987

* *Data collection period 1970-l 995

***Data collection period **1970-** 1995 for 60 to 100 inch diameter inlets

The data also suggests that the number of birds likely to be ingested into all engines during a flock encounter was inversely proportional to ‘the size of birds. These data were examined on an exceedence basis, and show that **95-percent** of the time no more than the following quantities of birds would be ingested into all engines on an aircraft during a flock encounter. As an example, the following quantities of birds ingested for engines in the 6,000 square-inch class are as follows:

Weight of Bird	Number of Birds
1.0-1.5	3
1.5-2.5	3

2.5+	2

considering the desire to evaluate multiple critical target locations on the face of the engine, this proposal selects a size of flocking bird that corresponds to a bird quantity of two or more birds. However, the FAA recognizes that there would be a residual risk of encounter of potentially larger bird sizes than specified in this proposed rule, and possibly greater quantities of birds than specified in this proposed rule. This proposal, however significantly increases the severity of the certification demonstration and provides a reduction in risk of a dual engine power loss due to flocking bird ingestion of any size and quantity.

In considering single large bird threats for sizes greater than that demonstrated under the medium flocking bird threat to multiple engines, the data analysis attempted to quantify exposure rates for birds weighing 4 Ibs. and up as a function of inlet throat area. Data from a series of FAA Technical Center reports published between 1990 and 1992 were used, in addition to the original AIA studies.

The data showed that small and medium engine sizes up to an inlet throat area of 2,100 square-inches had a relatively constant threat from birds greater than 4 lbs. at approximately **5E-7** ingestions per aircraft departure. Reports from the manufacturers also showed that this size of engine was more likely to ingest only portions of large birds, due to the much higher probability that an ingested bird may not enter the inlet on the engine centerline and, therefore, would strike the inlet structure and be dismembered before reaching the engine rotor blades. This conclusion is further substantiated by the absence of reports of unsafe engine shutdown due to single large birds greater than 4 lbs. for engines in this size range.

For engines with inlets larger than 2,100 square-inches, the rate of exposure to single large birds tracked roughly with increasing inlet size. The exposure rate for birds larger than 4 lbs. for the large population of engines with inlet surface areas in the 2,100 to 6,000 square-inch range was 1.5E-6 ingestions per aircraft departure. Review of the revenue service data however showed that medium and large turbofans exposed to single large birds above 4 lbs. have demonstrated safe shutdown characteristics as defined under § 33.75 even with bird sizes up to 15 lbs. The rate of unsafe shutdown occurrences in accordance with § 33.75 criteria was approximately one event per 120 occurrences. This unsafe shutdown rate was attributed to the blade-out containment test requirements of § 33.94 constituting a more severe test relative to safe shutdown criteria for almost all engines.

The intent of this proposed rule is to establish the single large bird size as a function of inlet surface area greater than 2,100 square-inches at a level where the exposure to birds beyond that specified in this proposed rule would be in the range of 1 E-6 to 1 E-7 ingestions per aircraft departure. This coupled with the prior service history record of satisfactory shutdown experience when exposed to very large birds, provides a potential improvement for hazardous consequences to continued safe flight into the extremely remote range of probability, i.e., 1E-7 to 1E-9.

This proposed rule conservatively establishes the single, large bird requirement for engines with inlet surface areas in the 2,100 to 6,000 square-inch range at 6 lbs. where the average exposure to larger birds was 8E-7 ingestions per aircraft departure. For engines with inlet surface areas greater than 6,000 square-inches, the requirement was increased to 8 lbs. to maintain an equivalent margin of safety.

The selection of the 200-knot ingestion speed for the large bird test was based on consideration of impact loading on the engine front stage blading. It was determined that for most current turbine engine designs, conducting the test at 250-knots (maximum allowed airspeed below 10,000-feet altitude) would likely result in a relatively low blade impact vector, which results in less than maximum bird impact forces on the blade(s). Coupled with the specified bird mass variations with engine inlet size, the proposed rule would fix the ingestion speed at 200-knots, and would require applicants to perform an analysis to determine the critical spanwise target location for a particular engine application.

Large turbofan engines certified to the medium bird requirements of § 33.77, amendment 33-6, which requires bird velocities of 250-knots, sustained in-service blade fractures and loss of power for ingested bird weights less than those demonstrated for certification test. Second generation turbofan engines certified under § 33.77, amendment 33- 10, used bird velocities which were equivalent to V_2 (takeoff safety speed) for the application aircraft (160 to 180-knots for the large transports). While the in-service record was significantly improved, these second generation engines were still experiencing blade fractures and power loss for bird weights less than the certification standard.

Engine ingestion parameters contributing to more than 50-percent power loss events were evaluated by AIA and AECMA. The most critical of the parameters evaluated which affected power loss were found to be bird weight, bird velocity, aiming point, and engine power setting. Each of these critical ingestion parameters have been evaluated in the proposed rule to determine the most severe conditions under which the medium bird test should be conducted.

The velocity to be used for the medium bird test was first established as the most critical velocity between V_1 (takeoff decision speed) and 250-knots indicated airspeed (KIAS) in order to cover the full range of takeoff and initial climb conditions that were considered to be potentially hazardous to the aircraft. In recognition of commuter and small business jet applications, the criterion was modified to reflect the fact that 250 KIAS was above the normal takeoff and climb speeds for this class of aircraft. A compromise criterion was chosen which required the medium bird ingestion velocity to be the most critical velocity between Vl and the velocity reached at 1,500.feet above ground level (AGL).

Bird strike data for rotorcraft are not as comprehensive as that available for fixed wing aircraft, probably for a variety of reasons associated with reporting standards, forward speed, low altitude operations, and the extensive use of inlet protection or inherent installation shielding on rotorcraft. The following helicopter bird ingestion data was reviewed in support of this proposal: (France) Direction Generale de L'Aviation Civile (DGAC), 1983 through 1990; (United Kingdom) Civil Aviation Authority (CAA), 1976 through 1987, and 1989 through 1990; (U.S.A.) FAA, 1985 through 1990; (Canada) Transport Canada, 1981 through 1989; and International Civil Aviation Organization (ICAO), 198 1 through 1989. The review showed reports of more than 600 bird strike events, but only four events were reported as-engine ingestions, and none were multiple events. Many of the 600 events involved flocks of small birds making engine ingestion very probable. Since there are no reports of significant power loss or mechanical damage it can be assumed that these ingestions had no affect on the engine.

The FAA did not find any records of hazardous events or service difficulties associated with engine bird ingestion in multi-engine rotorcraft operation. To require a rotorcraft engine to demonstrate medium bird ingestion capability will impose an unnecessary burden upon the design while producing no measurable safety benefit. The FAA, therefore, proposes that engines intended for use in multi-engine rotorcraft need not show compliance with the medium bird ingestion requirements of this proposed rule.

With respect to the actual test day conditions when demonstrations are made, this proposal considers the variability of engine performance as a function of changing ambient conditions. For example, substantial variations in engine rotor speed may take place between test demonstrations performed on cold days versus testing on hot days. These variations in rotor speed could in turn lead to variations in resulting damage, engine power, and operating characteristics. Even with no variation in blade damage, significant variations in power or other characteristics could be expected for conditions considerably different than for the test demonstration. Therefore, the FAA proposes to allow the actual test day ambient conditions and engine pretest conditions to vary, permitting equal flexibility among applicants and avoid conduct of engine tests in unrepresentative conditions which could lead to cycle mismatches. However, each applicant must account for these potential variations by extrapolation to other conditions specified in the type design. From the standpoint of power and operating characteristics, the applicant must show that the engine condition following bird ingestion can be extrapolated to that specified in the type design. Therefore, the FAA determined that the sea level, hot day, comer point represents a worst case set of ambient conditions for which to substantiate bird ingestion capability for both single large and flocking birds. From the standpoint of potential limit exceedences, the applicant must consider the worst performing production engine that is allowed by the type design.

The current rules consider the possibility of imminent failure following a bird ingestion encounter producing damage. Considering this possibility, the proposed rule recognizes the need to provide a positive margin to demonstrate run-on capability and the ability for an engine to safely function throughout a conservative time for an emergency return to the airport of departure immediately following a bird ingestion event. This scenario includes a recognition that the most critical encounters typically occur during heavy weight takeoffs and may require dumping of fuel before returning to land. During this period, it may be necessary to operate damaged engines throughout their operating cycle, including a need to make a go-around due to debris or equipment on the runway. This proposed rule would require the applicant to demonstrate the engine’s ability to operate satisfactorily during such circumstances. However, this proposal also recognizes that it is not possible to extend this demonstration to include all possible conditions occurring throughout a flight, particularly should the pilot decide to continue the flight to its originally intended destination. Lastly, considering the probable nature of bird ingestions, compliance with § 33.75 does not allow for circumstances which could lead to a hazardous failure as defined under that section. Therefore, seemingly normal operation of multiple damaged engines will not likely result in the failure of multiple engines within the same flight. For these reasons, there is no requirement within this proposed rule to further consider imminent failure after bird ingestion.

The EHWG also considered differences between part 33 and JAR-E with respect to the maximum emergency rating. The EHWG reached a consensus that there is no need to consider emergency ratings if it can be shown that the relative frequency of a bird ingestion event when using an emergency engine rating is less than 1E-8. Since part 33 does not define emergency ratings for turbofan engines, and the EHWG did not recommend that the FAA add that language, this proposal would not result in harmonizing part 33 with JAR-E in this regard.

Critical ingestion parameter tolerances were reviewed, and supporting arguments were made to justify the reasonableness of using a plus or minus lo-percent tolerance for variations within the test parameters. The application of this tolerance was discussed in the context of setting the engine speed and thrust parameters to test day takeoff conditions as described within this proposed rule. In contrast, the bird weight is controlled to "no less than" the weight specified within this proposed rule. The expectations of achieving the bird aim points and impact speed within plus or minus lo-percent or its equivalent regarding aim point was compared against the general collective test experience. A sensitivity analysis was conducted to evaluate the expected affect on thrust or power, should there be first stage blade damage, for variations in the following test parameters up to lo-percent: engine speed, bird speed, and target location. In general, these tolerances resulted in damage variations which produced approximately a 5-percent affect on thrust or power.

The EHWG determined that the current requirements of § 33.75 and JAR-E5 10 are not exactly the same, and, therefore, are not fully harmonized. The requirement of § 33.75 is restated in the proposed § 33.76 compliance criteria for the proposed medium and large bird ingestion tests. The bird ingestion requirements proposed by the JAA (Notice of Proposed Amendment (NPA-E-20)) includes a reference to JAR-E 5 10 for compliance criteria. However, the JAA compliance criteria is not the same as contained in this proposed rule. The FAA recognizes that full harmonization of § 33.75 and JAR-E 5 10 is still desirable, and will address this issue in future propulsion harmonization activities.

<u>Disposition of Minority Position (as stated in the NPA for the JAR on this subject)</u>

The JAA has expressed disagreement with a portion of this proposal, and is quoted as follows:

> The JAA expressed a dissenting opinion by requiring the new rules to include consideration of the threat which is created by flocking birds larger than 2.5 lb. The JAA proposed, in'the draft new rules, the imposition of an additional requirement for each engine having an inlet area of 2 100 square-inches or more. The applicant would be required to establish that when the fan assembly of such an engine is subjected to the ingestion of a single bird weighing at least 4 lb., under the same ingestion conditions as prescribed for the 6 lb. or 8 lb. bird ingestion test, the fan assembly retains sufficient integrity to demonstrate a total imbalance level less than 12 percent of the imbalance level corresponding to the loss of one complete fan blade airfoil.

The JAA rationale:

The stated aims of the draft new rules include reducing the risk of a dual engine power loss, the improvement goal being approximately 1E-8 or better per aircraft departure, and substantiation of that goal. The preamble also states that "unless the rule addresses the actual in-service bird threat, there can be no assurance that future designs would continue to exhibit acceptable capability". Allowing fan blades to be shown, during certification, as being less capable to withstand some sizes of birds than current in-service designs is not compatible with those stated aims.

The draft new rules (without the addition proposed by JAA) retain the same acceptance criteria for single large bird ingestion standard as in the existing rules. Extensive damage leading either to an immediate shutdown or necessitating a shutdown after 15 seconds is permitted, the only limit to the severity of the damage to the fan being safe containment, safe loads and no fire. However, in practice there are very good reasons for the manufacturers to establish that, with respect to containment, loads, fire, etc., the damage is not more severe than occurs with a full fan blade release. That practice is recognized in the draft new rules by a provision for waiving a full engine test demonstration of compliance with the large bird ingestion standard if it can be demonstrated that compliance with the requirements for containment of a full fan blade is a more severe demonstration.

Thus, because the minimum design allowed by the draft new rules is actually set primarily by the blade containment requirements, the large bird is allowed to cause extensive damage equivalent to that which results from the release of one entire fan blade. The increase of the weight of the large bird in the draft new rules, from 4 lb. to 6 lb. or 8 lb., will not improve the safety level if engines are designed to the minimum allowed by those new rules because it is a lower minimum that was demonstrated during certification of many, possibly most, of the current in-service engines. Further, it does not automatically follow that designing for a "safe" shutdown with a 6 lb. or 8 lb. bird results in a higher safety level than designing for a "safe" shutdown with a 4 lb. bird.

The certification tests on most of the types of large engines currently in service demonstrated that the 4 lb. bird certification ingestion test did not result in extensive damage to their fan blades. Therefore, the service experience which is the basis for the aims of the draft new rules is derived mainly from engines which were better during certification than required by the existing rules and better than can be allowed under the draft new rules without the JAA proposed addition.

The draft new rules require the large engines to retain a run-on and a 75 percent thrust capability when subjected to a multiple 2.5 lb. bird ingestion test but, as mentioned previously, the 6 lb. or 8 lb. bird ingestion is allowed to result in such extensive fan damage as to necessitate an immediate shutdown. In this case no information would then be available on the behavior of the fan in the event of a 4 lb. bird ingestion because the draft new rules do not address either medium (flocking) birds heavier than 2.5 lb. or large birds lighter than 6 lb. or 8 lb. The ingestion of a 4 lb. bird could, with some fan designs, also result in an immediate unavoidable engine shutdown.

There is already an example of a new engine which complies with the draft new rules for 2.5 lb. and 8 lb. bird ingestion's but the 8 lb. bird was shown to cause extensive damage commensurate with an immediate unavoidable shutdown. It would not have been possible,' from only that damage, to make any reasonable assessment of what damage would have resulted from a 4 lb. large bird certification test. Economic pressure could lead to an increased use of fan blades which are designed to the minimum allowed by the draft new rules because it provides an opportunity to reduce the weight of the fan blades, disc and containment ring.

Allowing new fan designs to be less capable than current in-service designs to withstand the ingestion of a 4 lb. bird would not be a concern if the multi-engine ingestion threat did not include birds weighing up to, and more than, 4 lb. However, the service experience supporting the draft new rules shows that the multiple engine ingestion rate for birds larger than 2.5 lb. is greater than 1E-7. With current in-service engines these events have resulted in a marginally acceptable risk of multi-engine shutdown. If no certification data is available to show that new designs are equal to, or better than, current designs at withstanding those birds, it must be assumed that such encounters will result in unavoidable multi-engine shutdowns at a rate of roughly 1E-7 which is in excess of the declared aim of 1E-8. The

JAA proposed additional requirement is intended to provide such certification data.

All parties involved in the development of the draft new rules recognize that flocking birds larger than 2.5 lb. may be encountered and the JAA does not disagree totally with the position that mitigation of this risk to 1E-8 or better per airplane departure cannot be economically provided entirely by available engine technology. However, the JAA believes that future engine fan technology must not be allowed to be less capable at mitigating that risk than current in-service engines.

Consequently the JAA concluded that the draft new rules are not achieving the stated aims by an amount that is more than necessary and not ensuring an achievable retention or improvement to the safety level by not ensuring that new fan designs are equal to, or better than, current designs at retaining their integrity when subjected to the ingestion of a 4 lb. bird under the conditions applicable to large bird ingestion requirements. The additional 4 lb. bird consideration proposed by JAA is intended to do no more than to provide some assurance of parity with current in-service fan designs, it is not intended to ensure a full run-on capability after the ingestion of a 4 lb. bird.

The FAA disagrees. The JAA position statement contains two major concerns: (1) that flocking birds larger than 2.5 lb. are a significant enough threat to require an evaluation for run-on capability; and (2) that this proposed rule may allow a lesser capable engine than those certified to the current rule with respect to medium flocking and single large bird ingestion.

With respect to JAA's first major concern, the FAA believes this proposed rule adequately addresses the flocking bird threat within the stated goal of this proposed rulemaking. That improvement goal is to reduce the risk of a dual engine power or thrust loss greater than 50-percent from current in-service rates to approximately 1E-8 or better per aircraft departure.

The worldwide bird ingestion threat database used for the medium and large engine portion of this proposed rulemaking includes substantial data from 1970 through 1995 and encompasses approximately 85-million aircraft flights. The database includes data for engine models with fan inlet diameters from 60 to 100 inches. This database shows the rate of multi-engine ingestions of birds larger than 2.5 lb. to be approximately 1E-7 per aircraft departure. The probability of a dual engine shutdown is predicted to be approximately 1E-8 per aircraft departure. This probability is based on the observed multi-engine ingestion rate and demonstrated rate of engine shutdown for ingestion of birds in this size range. These rates and probabilities are for engines certified to the current 1.5 lb. medium flocking and 4 lb. single large bird standards, which are less severe than this proposed rule.

The JAA position statement notes that the dual engine power loss and shutdown rate is marginally acceptable today. This proposed rule requires 2.5 lb. medium flocking birds and 6 to 8 lb. large single birds, depending on inlet size, both of which are more severe demonstrations, and which the FAA believes can only improve the overall worldwide fleet bird ingestion capability. This conclusion is also supported by the additional run-on evaluation requirements for the proposed medium bird test. Therefore, the FAA disagrees that additional run-on evaluation requirements for flocking birds larger than 2.5 lb. is necessary.

With respect to the JAA's second major concern for ingestion of medium flocking birds, the current marginally acceptable dual engine power loss rate relates primarily to engines certified to a 1.5 lb. bird ingestion requirement with 5 minutes of run-on. This proposed rule is for a 2.5 lb. bird with a 20 minute run-on evaluation requirement. This proposed rule represents a more severe design and test requirement than for engines certified to the current rule and should yield a more capable engine, not a less capable one. This requirement is supported by a test that is run to worst case conditions of fan speed, target location, number of birds, and new run-on evaluation requirements. The original review of historical data used in the development of this proposed rule showed that ingestion of single large birds greater than 2.5 lb. resulted in a significant engine power loss about 50-percent of the time, which was mostly due to mechanical damage to the fan. It is difficult to see how these earlier certified engines could have a greater ingestion capability than that demonstrated by a minimum engine that passes both the proposed 2.5 lb. medium flocking run-on and 6 to 8 lb. single large bird safe shutdown tests.

With respect to single large bird ingestion, the current marginally acceptable dual engine power loss rate relates primarily to engines certified to a 4 lb. single large bird safe shutdown requirement. With identical test criteria, an engine passing the proposed test will be at least as capable of a large bird safe shutdown as a current engine. Engine models that are tested using the proposed certification standards would have greater axial loads and greater local stresses on the impacted blades than for the 4 lb. requirement. Therefore, the blades must have greater capability with respect to a safe shutdown criteria. The FAA does not believe the proposed large bird ingestion criteria allows sufficient latitude such that an engine can pass the proposed 6 to 8 lb. test but not the current 4 lb. test. The proposal does not alter the current objective of a safe shutdown after a large bird ingestion.

The JAA also states that economic pressures could reduce the margin above the stated compliance criteria that engines may be designed for, and therefore result in less costly and less capable new designs of reduced margin when compared to engines currently in service. The FAA does not believe it is necessary to consider the margin above the certification standard with which any particular engine model demonstrates compliance, and that discussion of economic pressure has no place in objective evaluations of safety. The purpose of this proposed rule is to establish minimum certification requirements below which it is considered unsafe. Every engine meeting these proposed minimum requirements will be considered safe; either the regulatory criteria is appropriate, or it is not. Margin is not an issue when discussing properly chosen criteria. The FAA considers this proposed criteria as appropriate and, therefore, demonstrated margin above that criteria is not necessary. With respect to engines certified to the current

4 lb. single large bird ingestion safe shutdown test standard, some fan designs have exhibited blade fragmentation during the test while others have not. It is incorrect, however, to infer continued run-on capability simply from lack of fan blade fragmentation during the 1 S-second “hands-off’ period of the large bird ingestion test. Secondary damage and operability affects of continued high power operation with mechanical or aerodynamic unbalance, or both, would have to be taken into consideration.

It is also true that currently certified designs which have experienced fan blade fragmentation in large bird ingestion tests have accumulated well over 50-million hours in revenue service with a satisfactory bird ingestion record. The fact that these engines continue to operate and produce greater than 50-percent thrust in a significant percentage of revenue service large bird ingestion events, may well be attributable more to the combination of ingestion conditions being less severe than the certification test, rather than to the robustness of the fan design. The FAA expects this same mixed result will continue to occur in the single large bird ingestion certification test. In addition, such mixed results relative to fan blade fragmentation are not significant relative to this proposed rulemaking’s intent of improving the world fleet rate of dual engine power loss.

The FAA disagrees with the JAA statement that this proposed rule has a lower design minimum than the current rule. The FAA believes that this proposed rule significantly increases the certification standards for medium and large bird ingestion by increased severity of bird size, run-on, and target location. The test criteria of the current rule is less severe than that specified under this proposed rule, therefore, it cannot be described as providing a "greater margin" when compared to a marginally compliant engine under this proposed rule. Furthermore, no evidence has been offered to demonstrate' that engines certified under the current rule would always have a margin for run-on following the ingestion of a 4 lb. flocking bird. Thus, the arguments of current versus proposed criteria are considered subjective and unproven as indicators of future performance in service.

Consequently, for the reasons stated above, the FAA has concluded that evaluation of run-on capability for birds or ingestions larger than 2.5 lb. is not necessary to meet this proposed rulemaking objective, and therefore the JAA proposal does not need to be incorporated into this proposed rule.

General Discussion of the Proposals

Sections 23.903 (a)(2) and 25.903 (a)(2)

The proposal revises parts 23 and 25 requirements associated with foreign object ingestion into turbine engines to be consistent with the proposed part 33 requirements.

Section 33.76

The proposed new § 33.76 would contain the new bird ingestion requirements. This proposal was developed by the engine harmonization working group, and contains substantial common language that will be reflected both in part 33 and JAR-E. Also, the proposed new section adopts the approximate metric equivalents for certain test parameters to further commonality between part 33 and JAR-E.

Section 33.77

The proposed revisions to § 33.77 would remove the bird ingestion standards now specified in § 33.77 (a) and § 33.77 (b). Paragraphs (a) and (b) would be held in reserve. Paragraphs (d) and (e) would be revised to eliminate any reference to paragraphs (a) and (b). The table in paragraph (e) would be revised to remove bird ingestion standards.

Paperwork Reduction Act

As there are no requirements for information collection associated with this proposed rule, no analysis of paperwork requirements is required under the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.).

Regulatory Evaluation Summary

Four principal requirements pertain to the economic impacts of changes to the Federal regulations. First, Executive Order 12866 directs Federal agencies to promulgate new regulations or modify existing regulations after consideration of the expected benefits to society and the expected costs. The order also requires federal agencies to assess whether a proposed rule is considered a "significant regulatory action." Second, the Regulatory Flexibility Act of 1980 requires agencies to analyze the economic impact of regulatory changes on small entities. Third, the Office of Management and Budget directs agencies to assess the effect of regulatory changes on international trade. Finally, Public Law 104-4 requires federal agencies to assess the impact of any federal mandates on state, local, tribal governments, and the private sector.

In conducting these analyses, the FAA has determined that this proposed rule would generate cost-savings that would exceed any costs, and is not "significant" as defined under section 3 (f) of Executive Order 12866 and DOT policies and procedures (44 FR 11034, February 26, 1979). In addition, under the Regulatory Flexibility Determination, the FAA certifies that this proposal would not have a significant impact on a substantial number of small entities. Furthermore, this proposal would not impose restraints on international trade. Finally, the FAA has determined that the proposal would not impose a federal mandate on state, local, or tribal governments, or the private sector of $100 million per year. These analyses, available in the docket, are summarized below.

Cost and Benefits

The FAA estimates that the proposed rule would add $250,000 to $500,000 to each new engine model's certification costs, depending on engine inlet area. These costs would be incurred primarily in two areas. First, additional analysis required to verify the affects of a large bird impact on the front of the engine could necessitate a component test costing $250,000. Second, the proposed rule would require additional analysis or testing on the full fan assembly for engines with inlet areas greater than 2,092 square-inches. Such testing would cost an additional approximately $250,000 for those engines.

In addition, the revised bird test weights could necessitate strengthening fan components, thereby affecting fan performance. The FAA estimates that reduced fan efficiency would result in a 0.2-percent increase in fuel consumption. O-I average, this would increase annual fuel costs by $4,770 per airplane.

Benefits associated with the proposed rule include: (1) benefits from averted fatalities and injuries, (2) benefits from averted property damage (primarily hull losses), and (3) benefits associated with reduced maintenance and repair costs. Based on historical accident information, the FAA estimates that the expected annual per-airplane benefit from averted airplane damage or loss is approximately $657. The expected annual per-airplane benefit from averted fatalities and injuries is $654 and $75, respectively.

The estimated value of maintenance/repair savings associated with the proposed rule is based on an analysis of the relationship between bird ingestion weight and the probability of damage. The FAA estimates that, on average, the proposed rule would save operators approximately $4,654 per airplane per year.

To compare the costs and benefits of the proposed rule, the evaluation considers a hypothetical representative engine certification. The engines are assumed to be installed on a notional twin-engine jet transport with a seating capacity of 161 (the average seating capacity of jet transports in commercial service in 1996). In addition, this analysis assumes that: (1) the discount rate is 7-percent; (2) incremental engine certification costs equal $250,000 in year 0 and $250,000 in year 1, (3) production of engines commences in year 2, (4) engines are installed in aircraft and enter service beginning in year 3, (5) each engine has a 15-year service life, and (6) 24 engines are produced per year for 10 years so that there are 240 total engines and 120 airplanes per certification. Under these assumptions, the expected discounted benefits of the proposed rule would exceed discounted costs by a factor of 1.11 ($4,333,000 to $3,906,000).

International Trade Impact Analysis

The proposed rule would have little or no affect on international trade for either U.S. firms marketing turbine engines in foreign markets or foreign firms marketing turbine engines in the U.S.

Regulatory Flexibility Determination

The Regulatory Flexibility Act of 1980 establishes "as a principle of regulatory issuance that agencies shall endeavor, consistent with the objectives of the rule and of applicable statutes, to fit regulatory and informational requirements to the scale of the businesses, organizations, and governmental jurisdictions subject to regulation." To achieve that principle, the Act requires agencies to solicit and consider flexible regulatory proposals and to explain the rationale for their actions. The Act covers a wide range of small entities, including small businesses, not-for-profit organizations, and small governmental jurisdictions.

-Agencies must perform a preliminary analysis of all proposed rules to determine whether the rule will have a significant economic impact on a substantial number of small entities; if the determination is that it will, the agency must prepare an initial regulatory flexibility analysis (RFA).

However, if **after** a preliminary analysis for a proposed or final rule, an agency determines that a rule is not expected to have a significant economic impact on a substantial number of small entities, Section 605(b) of the Act provides that the head of the agency may so **certify.** The certification must include a statement providing the factual basis for this determination, and the reasoning should be clear.

The **FAA** conducted the required preliminary analysis of this proposal and determined that it will not have a significant economic impact on a substantial number of small entities. The following statement summarizes the basis for this determination. The proposed rule would apply only to newly designed turbine aircraft engines certificated in the future. Each new engine certification could affect two types of small entities.

First, the manufacturer would be required to perform additional analysis or testing to demonstrate that the proposed new bird ingestion requirements are met. There are currently nine turbine aircraft engine manufacturers with headquarters in the U.S. (this count includes subsidiaries of foreign entities and consortiums of domestic and/or foreign entities). Information available to the FAA at this time indicates that only one of these--a U.S. manufacturer of small turbine engines--has less than 1,500 employees and, therefore, qualifies as a small business under guidelines issued by the Small Business Administration.

It is diffkult to estimate total costs to this single manufacturer because these costs are a function of the number of engines certificated. The manufacturer is not expected to conduct bird ingestion testing in the foreseeable future. In view of this uncertainty, this analysis focuses on per engine costs for both manufacturers and operators. The proposed rule is estimated to add about $250,000 for a small engine type as currently manufactured by the single small entity (these are one time costs per certification). The FAA estimates that the proposed rule would impose no manufacturing costs. In light of the fact that there is only one known small business manufacturing turbine aircraft engines, and that manufacturer is not expected to be affected by the proposed rule in the foreseeable future, this analysis will assume that manufacturing costs imposed by this proposed rule will be passed on to operators who purchase the new engines and analyze these costs on small operators.

Aircraft operators would incur slightly higher engine prices, plus pay increased operating or fuel costs due to the small decrease in engine efficiency described in the full regulatory evaluation. According to FAA data, there are about 3,000 air carriers having less than 1,500 employees--approximately 100 air carriers operating under part 12 1 (or both part 12 1 and part 135) , and 2,900 air carriers operating under part 13 5.

Assuming conservatively that: (1) all incremental certification costs are passed on to the buyer/operator, (2) the manufacturer recovers incremental certification costs by applying a uniform price increase to 240 engines produced during a 1 O-year production run, and (3) that the discount rate is 7-percent; then the FAA estimates that average engine prices will increase by approximately $3,070 per larger engine and $1,587 per smaller engine. When these costs are amortized over the 15-year life of an engine (again, assuming a 7-percent discount rate), the incremental annualized cost per engine is approximately $3 15 and $163 for larger and smaller engines, respectively. Therefore, assuming a typical airplane has two engines, the incremental annualized cost for a large airplane is approximately $630 and the incremental annualized cost for a smaller airplane is approximately $326.

For larger engines, the rule will also increase annual airplane operating costs as a result of the proposed medium bird ingestion requirements (these requirements would have a negligible affect on smaller engines). On average, annual operating costs per large airplane, therefore, would increase by approximately $4,770. However, the reduction in average annualized maintenance costs associated with the more damage resistant engines that would be developed as a result of this proposed rule would almost completely offset incremental operating costs. These reduced maintenance costs are described more fully in the full regulatory evaluation.

Total annualized costs for operators of larger and smaller airplanes would therefore be approximately $630 and $326 per airplane, respectively. Consequently, the FAA makes an initial certification that the proposed rule would not have a significant economic impact on a substantial number of small entities.

Federalism Implications

The regulations proposed herein would not have substantial direct affects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government; and would not impose substantial direct compliance costs on States or local governments. Therefore, in accordance with Executive Order 126 12, it is determined that this proposal would not have sufficient federalism implications to require consultation with representatives of affected States and local governments.

In addition, the regulations proposed herein would not significantly or uniquely affect the communities of the Indian tribal governments and would not impose substantial direct compliance costs on such communities. Therefore, in accordance with Executive Order 13084, it is determined that this proposal would not require consultation with representatives of affected Indian tribal governments.

Environmental Assessment

FAA Order 1050. ID defines FAA actions that may be categorically excluded from preparation of a National Environmental Policy Act (NEPA) environmental assessment (EA) or environmental impact statement (EIS). In accordance with FAA Order 1050. 1D, appendix 4, paragraph 4(j), regulations, standards, and exemptions (excluding those, which if implemented may cause a significant impact on the human environment) qualify for a categorical exclusion. The FAA has determined that this rule qualifies for a categorical exclusion because no significant impacts to the environment are expected to result from its finalization or implementation. In accordance with FAA Order 1050. 1D, paragraph 32, the FAA has determined that there are no extraordinary circumstances warranting preparation of an environmental assessment for this proposed rule.

List of Subjects in 14 CFR Parts 23, 25 and 33.

Air transportation, Aircraft, Aviation safety, Safety.

~~**List of Subjects in 14 CFR Part 25**~~

~~**Air transportation, Aircraft, Aviation safety, Safety.**~~

~~**List of Subjects in 14 CFR Part 33**~~

~~Air **transportation,** Aircraft, Aviation safety, Safety.~~

The Proposed Amendment

In consideration of the foregoing, the Federal Aviation Administration propose5 to amend parts 23, 25 and 33 of Title 14, Code of Federal Regulations as follows:

PART 23- AIRWORTHINESS STANDARDS: NORMAL, UTILITY, ACROBATIC, AND COMMUTER CATEGORY AIRPLANES

1. The authority citation for part 23 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701, 44702, 44704.

2. Section 23.903 is amended by revising paragraph (a)(2) to read as follows:

§ 23.903 Engines.

(a * * *

(2) Each turbine engine and its installation must comply with one of the following:

(i) Sections 33.76, 33.77 and 33.78 of this chapter in effect on **(effective date of final rule),** or as subsequently amended; or

(ii) Sections 33.77 and 33.78 of this chapter in effect on April 30, 1998, or as subsequently amended before **(effective date of final rule);** or

(iii) Section 33.77 of this chapter in effect on October 3 1, 1974, or as subsequently amended before April 30, 1998, unless that engine's foreign object ingestion service history has resulted in an unsafe condition; or

(iv) Be shown to have a foreign object ingestion service history in similar installation locations which has not resulted in any unsafe condition.

* * * * *

PART 25 - AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

3. The authority citation for part 25 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701, 44702, 44704.

4. Section 25.903 is amended by revising paragraph (a)(2) to read as follows:

§ 25.903 Engines.

(a * * *

(2) Each turbine engine must comply with one of the following:

(i) Sections 33.76, 33.77 and 33.78 of this chapter in effect on **(effective date of final rule),** or as subsequently amended; or

(ii) Sections 33.77 and 33.78 of this chapter in effect on April 30, 1998, or as subsequently amended before **(effective date of final rule);** or

(iii) Comply with § 33.77 of this chapter in effect on October 3 1, 1974, or as subsequently amended prior to April 30, 1998, unless that engine's foreign object ingestion service history has resulted in an unsafe condition; or

(iv) Be shown to have a foreign object ingestion service history in similar installation locations which has not resulted in any unsafe condition.

* * * * *

PART 33 - AIRWORTHINESS STANDARDS: AIRCRAFT ENGINES

5. The authority citation for part 33 continues to read as follows:

hthority: 49 U.S.C. 106(g), 40113, 44701, 44702, 44704.

6. Section 33.76 is added to read as follows:

§ 33.76 Bird Ingestion.

(a) General. Compliance with paragraphs (b) and (c) of this section shall be in accordance with the following:

(1) Ail ingestion tests shall be conducted with the engine stabilized at no less than loo-percent takeoff power or thrust for test day ambient conditions prior to the ingestion. In addition, the demonstration of compliance must account for engine operation at sea level takeoff conditions on the hottest day that a minimum engine can achieve maximum rated takeoff thrust or power.

(2) The engine inlet area as used in this section to determine the bird quantity and weights will be established by the applicant and identified as a limitation on the inlet throat area in the installation instructions required under § 33.5.

(3) The impact to the front of the engine from the single large bird and the single largest medium bird which can enter the inlet must be evaluated. It must be shown that the associated components when struck under the conditions prescribed

in paragraphs (b) or (c) of this section, as applicable, will not affect the engine to the extent that it cannot comply with the requirements of paragraphs (b)(3) and (c)(6) of this section.

(4) For an engine that incorporates an inlet protection device, compliance with this section shall be established with the device functioning. The engine approval will be endorsed to show that compliance with the requirements has been established with the device functioning.

(5) Objects that are accepted by the Administrator may be substituted for birds when conducting the bird ingestion tests required by paragraphs (b) and (c) of this section.

(6) If compliance with the requirements of this section is not established, the engine type certification documentation will show that the engine shall be limited to aircraft installations in which it is shown that a bird cannot strike the engine, or be ingested into the engine, or adversely restrict airflow into the engine.

(b) Large birds. Compliance with the large bird ingestion requirements shall be in accordance with the following:

(1) The large bird ingestion test shall be conducted using one bird of a weight determined from Table 1 aimed at the most critical exposed location on the first stage rotor blades and ingested at a bird speed of 200 knots for engines to be installed on airplanes, or the maximum airspeed for normal rotorcraft flight operations for engines to be installed on rotorcraft.

(2) Power lever movement is not permitted within 15 seconds following ingestion of the large bird.

(3) Ingestion of a single large bird tested under the conditions prescribed in this section may not cause the engine to:

(i) Catch fire;

(ii) Release hazardous fragments through the engine casing;

(iii) Generate loads greater than those ultimate loads specified under § 33.23(a); or

(iv) Lose the ability to be shut down.

(4) Compliance with the large bird ingestion test requirements of this paragraph may be waived if it can be demonstrated that the containment requirements of § 33.94(a) constitute a more severe demonstration than the requirements of this paragraph.

Table 1
Large Bird Weight Requirements

Engine Inlet Area (A) square-meters (square-inches)	Bird Weight kg. (lb.)
1.35 (2,092) > A	1.85 (4.07) minimum, unless a smaller bird is determined to be a more severe demonstration.
1.35 (2,092) ≤ A < 3.90 (6,045)	2.75 (6.05)
3.90 (6,045) ≤ A	3.65 (8.03)

(c) Small and medium birds. Compliance with the small and medium bird ingestion requirements shall be in accordance with the following:

(1) Analysis or component test, or both, acceptable to the Administrator, shall be conducted to determine the critical ingestion parameters affecting power loss and damage. Critical ingestion parameters shall include, but are not limited to, the affects of bird speed, critical target location, and first stage rotor speed. The critical bird ingestion speed should reflect the most critical condition within the range of airspeeds used for normal flight operations up to 1,500 feet above ground level, but not less than V_1 minimum for airplanes.

(2) Medium bird engine tests shall be conducted so as to simulate a flock encounter, and will use the bird weights and quantities specified in Table 2. When only one bird is specified, that bird will be aimed at the engine core primary flow path; the other critical locations on the engine face area must be addressed, as necessary, by appropriate tests or analysis, or both. When two or more birds are specified in Table 2, the largest of those birds must be aimed at the engine core primary flow path, and a second bird must be aimed at the most critical exposed location on the first stage rotor blades. Any remaining birds must be evenly distributed over the engine face area.

(3) In addition, except for rotorcraft engines, it must also be substantiated by appropriate tests or analysis or both, that when the full fan assembly is subjected to the ingestion of the quantity and weights of birds from Table 3, aimed

at the fan assembly's most critical location outboard of the primary core flowpath, and in accordance with the applicable test conditions of this paragraph, that the engine can Comply with the acceptance criteria of this paragraph.

(4) A small bird ingestion test is not required if the prescribed number of medium birds pass into the engine rotor blades during the medium bird test.

(5) Small bird ingestion tests shall be conducted so as to simulate a flock encounter using one 85 gram (0.187 lb.) bird for each 0.032 square-meter (49.6 square-inches) of inlet area, or fraction thereof, up to a maximum of 16 birds. The birds will be aimed so as to account for any critical exposed locations on the first stage rotor blades, with any remaining birds evenly distributed over the engine face area.

(6) Ingestion of small and medium birds tested under the conditions prescribed in this paragraph may not cause any of the following:

(i) More than a sustained 25-percent power or thrust loss;

(ii) The engine to be shut down during the required run-on demonstration prescribed in subparagraphs (c)(7) or (c)(8) of this section;

(iii) The conditions defined in subparagraph (b)(3) of this section.

(iv) Unacceptable deterioration of engine handling characteristics.

(7) Except for rotorcraft engines, the following test schedule shall be used:

(i) Ingestion so as to simulate a flock encounter, with approximately 1 second elapsed time from the moment of the first bird ingestion to the last.

(ii) Followed by 2 minutes without power lever movement after the ingestion.

(iii) Followed by 3 minutes at 75 percent of the test condition.

(iv) Followed by 6 minutes at 60 percent of the test condition.

(v) Followed by 6 minutes at 40 percent of the test condition.

(vi) Followed by 1 minute at approach idle.

(vii) Followed by 2 minutes at 75 percent of the test condition.

(viii) Followed by stabilizing at idle and engine shut down.

The durations specified are times at the defined conditions with the power lever being moved between each condition in less than 10 seconds.

(8) For rotorcraft engines, the following test schedule shall be used:

(i) Ingestion so as to simulate a flock encounter within approximately 1 second elapsed time between the first ingestion and the last.

(ii) Followed by 3 minutes at 75 percent of the test condition.

(iii) Followed by 90 seconds at descent flight idle.

(iv) Followed by 30 seconds at 75 percent of the test condition.

(v) Followed by stabilizing at idle and engine shut down. The duration specified are times at the defined conditions with the power being changed between each condition in less than 10 seconds.

(9) Engines intended for use in multi-engine rotorcraft are not required to comply with the medium bird ingestion portion of this section, providing that the appropriate type certificate documentation is so endorsed.

(10) If any engine operating limit(s) is exceeded during the initial 2 minutes without power lever movement, as provided by subparagraph (c)(7)(ii) of this section, then it shall be established that the limit exceedence will not result in an unsafe condition.

Table 2
Medium Flocking Bird Weight & Quantity Requirements

Engine Inlet Area (A) square-meters(square-inches)	Bird Quantity	Bird Weight kg.(lb.)
0.05 (77.5) > A	none	------
.05 (77.5) ≤ A < 0.10 (155)	1	0.35 (0.77)
0.10 (155) ≤ A < 0.20(310)	1	0.45 (0.99)
0.20 (310) ≤ A < 0.40 (620)	2	0.45 (0.99)
0.40 (620) ≤ A < 0.60 (930)	2	0.70 (1.54)
0.60 (930) ≤ A < 1.00 (1,550)	3	0.70 (1.54)
1.00 (1,550) ≤ A < 1.35 (2,092)	4	0.70 (1.54)
1.35 (2,092) ≤ A < 1.70 (2,635)	1	1.15 (2.53)
	plus 3	0.70 (1.54)
1.70 (2,635) ≤ A < 2.10 (3,255)	1	1.15 (2.53)
	plus 4	0.70 (1.54)
2.10 (3,255) ≤ A < 2.50 (3,875)	1	1.15 (2.53)
	plus 5	0.70 (1.54)
2.50 (3,875) ≤ A < 3.90 (6045)	1	1.15 (2.53)
	plus 6	0.70 (1.54)
3.90 (6045) ≤ A < 4.50 (6975)	3	1.15 (2.53)
4.50 (6975) ≤ A	4	1.15 (2.53)

Table 3
Additional Integrity Assessment

Engine Inlet Area (A) -square-meters(square-inches)	Bird Quantity	Bird Weight kg.(lb.)
1.35 (2,092)’ A	none	------
1.35 (2,092)≤ A < 2.90 (4,495)	1	1.15 (2.53)
2.90 (4,495)≤ A < 3.90 (6,045)	2	1.15 (2.53)
3.90 (6,045)≤ A	1	1.15 (2.53)
	plus 6	0.70 (1.54)

7. Section 33.77 is amended by removing and reserving paragraphs (a) and (b) and by revising paragraphs (d)(3) and (e) to read as follows:

§ 33.77 Foreign object ingestion.

* * * * *

(d) * * *

(3) The foreign object, or objects, stopped by the protective device will not obstruct the flow of induction air into the engine with a resultant sustained reduction in power or thrust greater than those values required by paragraph (c) of this section.

(e) Compliance with paragraph (c) of this section must be shown by engine test under the following ingestion conditions:

Foreign object	Test quantity	Speed of foreign object	Engine operation	Ingestion
Ice...	Maximum accumulation on a typical inlet cowl and engine face resulting from a 2-minute delay in actuating anti-icing system, or a slab of ice which is comparable in weight or thickness for that size engine.	Sucked in........	Maximum cruise.	To simulate a continuous maximum icing encounter at 25 degrees Fahrenheit.

Issued in Washington, DC, on December 2, 1998.

Elizabeth Erickson

Elizabeth Erickson
Director, Aircraft Certification Service

U.S. Department of
Transportation

FEDERAL AVIATION ADMINISTRATION

Washington, D.C. 20591

PRELIMINARY REGULATORY EVALUATION, INITIAL REGULATORY FLEXIBILITY DETERMINATION, AND TRADE IMPACT ASSESSMENT

Airworthiness Standards; Bird Ingestion Standards

Proposed Rule
(14 CFR Part 33)

Office of Aviation Policy and Plans
Aircraft Regulatory Analysis Branch, APO-320

January 13, 1998

Table of Contents

Executive Summary

This regulatory evaluation estimates the benefits and costs of a proposed rule to revise Title 14 part 33 of the Code of Federal Regulations (CFR) by introducing additional bird ingestion tolerance requirements for aircraft turbine engines. The rule would consolidate existing and new bird ingestion standards in proposed §33.76. Concomitantly, bird ingestion standards now specified in §33.77(a) and (b) would be removed. In addition, 14 CFR parts 23 and 25 would be amended consistent with the proposed changes to part 33. The rule's major provisions--relating to large, medium, and small birds--are summarized below.

Revised large bird ingestion standards. Current regulations preclude fire, burst, the generation of unsafe loads, or the loss of shutdown capability following the ingestion of a single 4 pound bird. The proposal would amend this requirement in several ways.

First, the proposed rule [§33.76(a)(3)] would require testing or analysis to verify that a large bird strike against associated engine components (such as the nose cone/spinner, inlet guide vane assemblies, and engine protection devices) would not affect the engine to the extent that it cannot comply with the ingestion test acceptance criteria specified in proposed §33.76(b)(3) and §33.76(c)(6).

Second, the rule would establish a schedule of large bird test weights which would vary as a function of engine inlet area from approximately 4 pounds (for engines with an inlet area of less than 2,092 square inches) to approximately

8 pounds (for engines with an inlet area of 6,045 square inches or more) [Table 1 of proposed §33.76(b)]. These revised standards would more accurately represent the bird threat observed in service.

Finally, proposed §33.76(b)(4) would allow manufacturers to forego the large bird test if it can be shown that the containment standards of §33.94(a) (blade containment and rotor unbalance tests) constitute a more severe requirement.

Revised medium bird ingestion standards. The proposal would also modify the standards for medium bird ingestion. The current rule requires. a test simulating a flock encounter with 1.5 pound birds, where bird quantity is a function of the inlet area (up to a maximum of eight birds). Under proposed §33.76(c)(2), both bird weight and quantity would be functions of the inlet area. In addition to these weight and quantity modifications, the proposed rule would revise medium bird ingestion test procedures. Bird speed--currently specified as the initial climb speed of a typical aircraft--would, under the proposed rule, be determined by analysis or testing as part of the identification of critical ingestion parameters (e.g. bird speed, target locations, first stage rotor speed) [proposed §33.76(c)(1)]. Also, the proposed medium and small bird tests would require an engine to be run for 20 minutes following ingestion (current regulations call for a 5 minute run-on) [proposed §33.76(c)(7)].

Revised small bird ingestion standards. While small bird weights and quantities would be unaffected by the proposed rule, test procedures would be revised in a fashion similar to the medium bird tests: 1) bird speed would be determined as part of the critical ingestion parameter analyses [proposed §33.76(c)(1)], and 2) the ingestion test schedule would include 20 minutes of post-ingestion engine operation [proposed §33.76(c)(7)].

Incremental costs. Considered together, FAA estimates that these provisions would add $250,000 to $500,000 to certification costs depending on engine inlet area. The additional analysis required to verify the effects of a large bird impact on the front of the engine could necessitate a component test costing $250,000. Also, the rule would require additional analysis or testing on the full fan assembly for engines with inlet areas greater than 2,092 square inches. Such testing would cost approximately $250,000.

In addition, the revised medium bird test weights could necessitate strengthening fan components, thereby affecting fan performance. FAA estimates that reduced fan efficiency would result in a 0.2% increase in fuel consumption. On average, this would increase annual fuel costs by $4,770 per airplane.

Benefits. Benefits associated with the proposed rule include: 1) benefits from averted fatalities and injuries, 2) benefits from averted property damage (primarily hull losses), and 3) benefits associated with reduced maintenance and repair costs. Based on historical accident data and information obtained from industry, FAA estimates that the expected annual per-airplane benefit from averted airplane damage or loss is approximately $657. The expected annual per-airplane benefit from averted fatalities and injuries is $654 and $75, respectively.

The estimated value of maintenance/repair savings associated with the proposed rule is based on an analysis of the relationship between bird ingestion weight and the probability of damage. FAA estimates that, on average, the rule would save operators approximately $4,654 per airplane per year.

Comparison of benefits and costs. In order to compare the costs and benefits of the proposed rule, the evaluation considers a hypothetical representative engine certification. The engines are assumed to be installed on a notional twin-engine jet transport with a seating capacity of 161 (the average seating capacity of jet transports in commercial service in 1996). In addition, this analysis assumes that: 1) the discount rate is 7%, 2) incremental engine certification costs equal $250,000 in year 0 and $250,000 in year 1, 3) production of engines commences in year 2, 4) engines are installed in aircraft and enter service beginning in year 3, 5) each engine has a 15-year service life, 6) 24 engines are produced per year for 10 years so that there are 240 total engines and 120 airplanes per certification. Under these assumptions, the expected discounted benefits of the proposed rule would exceed discounted costs by a factor of 1.11 ($4,333,000 to $3,906,000)

Regulatory *Flexibility Detennination.* The Regulatory Flexibility Act of 1980 establishes "as a principle of regulatory issuance that agencies shall endeavor, consistent with the objectives of the rule and of applicable statutes, to fit regulatory and informational requirements to the scale of the businesses, organizations, and governmental jurisdictions subject to regulation." To achieve that principle, the Act requires agencies to solicit and consider flexible regulatory proposals and to explain the rationale for their actions. The Act covers a wide range of small entities, including small businesses, not-for-profit organizations and small governmental jurisdictions.

Agencies must perform a preliminary analysis of all proposed rules to determine whether the rule will have a significant economic impact on a substantial number of small entities; if the determination is that it will, the agency must prepare an initial regulatory flexibility analysis (RFA).

However, if after a preliminary analysis for a proposed or final rule, an agency determines that a rule is not expected to have a significant economic impact on a substantial number of small entities, Section 605(b) of the 1980 act provides that the head of the agency may so certify. The certification must include a statement providing the factual basis for this determination, and the reasoning should be clear.

The FAA has conducted the required preliminary analysis of this proposal and determined that it will not have a significant economic impact on a substantial number of small entities. The following statement summarizes the basis for this determination.

The proposed rule would apply only to newly designed turbine aircraft engines certificated in the future. Each new engine certification could affect two types of small entities.

First, the manufacturer would be required to perform additional analysis or testing to demonstrate that the proposed new bird ingestion requirements are met. There are currently 9 turbine aircraft engine manufacturers with headquarters in the U.S. (this count includes subsidiaries of foreign entities, and consortiums of domestic and/or foreign entities). Information available to the FAA at this time indicates that only one of these--a U.S.

manufacturer of small turbine engines--has less than 1,500 employees and therefore qualifies as a small business under guidelines issued by the Small Business Administration.

It is difficult to estimate total costs to this single manufacturer because these costs are a function of the number of engines' certificated. This manufacturer is not expected to conduct bird ingestion testing in the foreseeable future. In view of this uncertainty, this analysis focuses on per engine costs for both manufacturers and operators.

The proposed rule is estimated to add about $250,000 for a small engine type as currently manufactured by the single small entity (these are one time costs per certification). The FAA estimates that the proposed rule would impose no manufacturing costs. In light of the fact that' there is only one known small business manufacturing turbine aircraft engines, and that manufacturer is not expected to be affected by the proposed rule in the foreseeable future, this analysis will assume that manufacturing costs imposed by this proposed rule will be passed on to operators who purchase the new engines and analyze these costs on small operators.

Aircraft operators would incur slightly higher engine prices, plus pay increased operating or fuel costs due to the small decrease in engine efficiency described in the full regulatory evaluation. According to FAA data, there are about 3,000 air carriers having less than 1,500 employees--approximately 100 part 121 (or dual 121/135 certificate) air carriers, and 2,900 part 135 air carriers

Assuming conservatively that: 1) all incremental certification costs are passed on to the buyer/operator, 2) the manufacturer recovers incremental certification costs by applying a uniform price increase to 240 engines produced during a ten year production run, and 3) that the discount rate is 7 percent; then the FAA estimates that average engine prices will increase by approximately $3070 per larger engine and $1587 per smaller engine. When these costs are amortized over the **15-year** life of an engine (again, assuming a 7% discount rate), the incremental annualized cost **per** engine is approximately $315 and $163 for larger and smaller engines, respectively. Therefore, assuming **a** typical airplane has two engines, the incremental annualized cost for **a** large airplane is approximately $630 and the incremental annualized cost for **a** smaller airplane is approximately $326.

For larger engines, the rule will also increase annual airplane operating costs as **a** result of the proposed medium bird ingestion requirements (these requirements would have a negligible effect on smaller engines). On **average,** annual operating costs per large airplane, therefore, would increase by approximately $4,770 (see Table 1). However, the reduction in average annualized maintenance costs, associated with the more damage resistant engines that would be developed **as a** result of this rule, would almost completely offset incremental operating costs. These reduced maintenance costs are described more fully in the full regulatory evaluation.

Total annualized costs for operators of larger and smaller airplanes would therefore be approximately $630 and $326 per airplane, respectively. Consequently, the FAA makes an initial certification that the proposed rule would not have a significant economic impact on a substantial number of small entities.

International Trade Impact Assessment. The proposed rule would have little or no effect on trade for either domestic firms marketing turbine engines in foreign markets or foreign firms marketing turbine engines in the United States.

Airworthiness Standards: Bird Ingestion *Standards*

I. Introduction'

This regulatory evaluation estimates the benefits and costs of a proposed rule to revise Title 14 part 33 of the Code of Federal Regulations (CFR) by introducing additional bird ingestion tolerance requirements for aircraft turbine engines. The rule would consolidate existing and new bird ingestion standards in proposed §33.76. Concomitantly, bird ingestion standards now specified in §33.77(a) and (b) would be removed. In addition, 14 CFR parts 23 and 25 would be amended consistent with the proposed changes to part 33. The rule's major provisions are summarized below.

A. Revised large bird ingestion standards

Current regulations preclude fire, burst, the generation of unsafe loads, or the loss of shutdown capability following the ingestion of a single 4 pound bird. The proposal would amend this requirement in several ways.

First, the proposed rule [§33.76(a)(3)] would require testing or analysis to verify that a large bird strike against associated engine components (such as the nose cone/spinner, inlet guide vane assemblies, and engine protection devices) would not affect the engine to the extent that it cannot comply with the ingestion test acceptance criteria specified in proposed §33.76(b)(3) and §33.76(c)(6).

Second, the rule would establish a schedule of large bird test weights which would vary as a function of engine inlet area from approximately 4 pounds (for engines with an inlet area of less than 2,092 square inches) to approximately 8 pounds (for engines with an inlet area of 6,045 square inches or more) [Table 1 of proposed §33.76(b)]. These revised standards would more accurately represent the bird threat observed in service.

Finally, proposed §33.76(b)(4) would allow manufacturers to forego the large bird test if it can be shown that the containment standards of §33.94(a) (blade containment and rotor unbalance tests) constitute a more severe requirement.

B. Revised medium bird ingestion standards

The proposal would also modify the standards for medium bird ingestion. The current rule requires a test simulating a flock encounter with 1.5 pound birds, where bird quantity is a function of the inlet area (up to a maximum of eight birds). Under proposed §33.76(c)(2), both bird weight and quantity would be functions of the inlet area.

In addition to these weight and quantity modifications, the proposed rule would revise medium bird ingestion test procedures. Bird speed--currently specified as the initial climb speed of a typical aircraft--would, under the proposed rule, be determined by analysis or testing as part of the identification of critical ingestion parameters (e.g. bird speed, target locations, first stage rotor speed) [proposed §33.76(c)(1)]. Also, the proposed medium and small bird tests would require an engine to be run for 20 minutes following ingestion (current regulations call for a 5 minute run-on) [proposed §33.76(c)(7)].

C. Revised small bird ingestion standards

While small bird weights and quantities would be unaffected by the proposed rule, test procedures would be revised in a fashion similar to the medium bird tests: 1) bird speed would be determined as part of the critical ingestion parameter analyses [proposed §33.76(c)(l)], and 2) the ingestion test schedule would include 20 minutes of post-ingestion engine operation [proposed §33.76(c)(7)].

II. Background

Depending on their mass and quantity, ingested birds can impede turbine engine operation to varying degrees. Damage can include: 1) bent fan blades (which reduce fan efficiency), 2) transverse blade fractures (in which a fan blade is broken chordwise, perhaps causing secondary damage to the engine), or 3) core damage (bent or broken compressor blades or vanes, perhaps involving blocked or disrupted airflow in the low, intermediate, or high pressure compressors).

Currently, aircraft turbine engines must be capable of ingesting a four pound bird without potentially hazardous consequences such as fire, ejection of engine fragments through the case, or the loss of shutdown capability. This requirement is referred to as the "safe shutdown" criterion. The medium and small bird tests--which address situations where a multiple engine event is more likely--are designed to verify that an engine can continue to operate with no more than a 25 percent power loss after ingestion.

The origins of existing turbine engine bird ingestion standards can be traced to the early 1960's when the FAA issued a series of advisory circulars that outlined foreign object ingestion requirements. In June of 1969, industry and government officials met at an agency sponsored conference to discuss ways of improving aircraft engine certification requirements. Some of the ideas advanced at that conference were incorporated into a proposed rule published in May 1971 (36 FR 8383) and published in final form in October 1974 (39 FR 35467). The new regulations defined certification requirements for foreign object ingestion (533.77) and, in particular, established the bird ingestion test trichotomy that exists today: 1) up to 16 3-ounce birds ingested in rapid sequence to simulate a flock encounter, 2) up to eight 1.5 pound birds ingested in rapid sequence to simulate a flock encounter, and 3) one 4-pound bird aimed at a critical area. A subsequent rulemaking, published on February 23, 1984 (49 FR 6852) clarified engine test and design requirements and upgraded certain standards (including bird ingestion test procedures) to account for the increasing complexity of aircraft engines.

This rulemaking arises from a number of studies conducted by the FAA, the Aerospace Industries Association (AIA) and the Association Europeenne Des Constructeurs de Materiel Aerospatial (AECMA). These studies show that despite current design requirements, bird ingestions are still a persistent hazard. For example, the ingestion rate for large high bypass ratio turbofan engines is approximately 2.04×10^{-4} ingestions per aircraft operation. Half of these cases result in damage to the engine and one-eighth of these events require crew action (e.g. aborted takeoffs, diversions). Approximately 2.4 percent of the cases result in an inflight shut-down of the engine.[1]

III. Economic Analysis

A. Incremental costs

1. Incremental costs associated with the large bird amendments

Under existing regulations, engine manufacturers must show that the ingestion of a large bird will not cause a hazardous condition [as described in §33.77(a)]. In practice, this requirement can be met by demonstrating that §33.94 (blade containment and rotor imbalance) represents a more severe test. Proposed §33.76(b)(4) simply codifies this policy and so would not affect certification costs.

Proposed §33.76(b)(1) would increase large bird weight from 4 pounds to as much as 8 pounds depending on inlet size. 'According to industry representatives, however, this provision would have little effect on the cost of future engine certifications. This follows for several reasons. First, there is no change in specified bird weights for engines with inlet sizes less than 2,092 square inches. Second, engine manufacturers are already responding to air carrier (in particular, operators of large twin engine transport aircraft) demand for engines with greater bird ingestion tolerance. Finally,

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[1] Banilower, Howard, Bird Ingestion into Large Turbofan Engines, U.S. Department of Transportation, Federal Aviation Administration, DOT/FAA/CT-93-14, February, 1995, p xi.

for recent designs, the existing blade-out requirement (§33.94) has proven to be a more severe test than the proposed large bird requirement.[2]

The proposal would also require additional analysis or testing to verify the effects of a large bird impact on the front of the engine. This demonstration could require a component test costing $250,000. Industry representatives state, however, that future engine designs meeting the large bird requirements of these amendments will be able to meet the engine-front impact requirement without incurring additional manufacturing costs or weight or performance penalties. There are expected to be small performance penalties associated with meeting the medium/small bird amendments as discussed in the next section.

2. Incremental costs associated with the medium/small bird amendments

Several amendments to the medium and small bird ingestion standards would result in little or no incremental cost:

1) §33.76(a)(3) would require evaluation of a medium bird strike against the front of the engine. Although this is not explicitly contained in 14 CFR Part 33, existing FAA policy requires the consideration of an engine-front impact as part of medium and small bird ingestion analyses.

[2] According to one expert, this result is likely to persist given modern, wide-chord, fan blade designs. Although fan blades for large turbine engines can weigh as much as 40 pounds, it is theoretically possible that a large bird impact could affect a greater number of adjacent blades (thereby producing more severe rotor imbalance) than a single blade-out. Thus, component testing or analysis is required to verify which is the more severe test. Also, the relative severity of the two tests varies with engine size.

2) §33.76(a)(1) would require manufacturers to account for engine operation at sea level take-off conditions on the hottest day that a minimum engine can achieve maximum rated take-off thrust or power. Industry representatives state that this provision would generate little incremental costs.

3) §33.76(c)(7) would require the test engine to be run for 20 minutes (at various specified power levels) following bird ingestion. The existing regulation calls for 5-minutes of engine operation. FAA and industry representatives judge the incremental costs associated with this provision to be negligible.

4) §33.76(c)(9) would waive compliance with the test provisions of §33.76(c)(1)-(8) for engines limited to multi-engine rotorcraft installations. This change is expected to reduce manufacturing and operating costs.

a. Engines with inlet areas greater than 2,092 square inches

The proposed rule would raise medium bird ingestion standards for engines with inlet areas greater than 2,092 square inches. It would mandate additional testing or analysis on the full fan assembly and would also increase the weight of the largest medium test bird (Table 2 as proposed in the NPRM). Based on discussions with industry, the FAA estimates that the required full fan assembly analysis or rig test would cost approximately $250,000.

Incremental certification and manufacturing costs associated with the proposed medium bird weight revision are expected to be negligible. However, the revised test weight would necessitate strengthening fan components, thereby affecting fan performance. One manufacturer estimates that reduced fan efficiency would result in a 0.2% increase in fuel consumption. The average annual per airplane effect on fuel consumption is computed in Table 1.

Table 1.--Incremental Fuel Consumption Under the-Proposed Rule
(Incremental fuel cost per aircraft per year in 1996 dollars)

AC Category	Gal/hr per AC (1)	0.2% Effect (2)	Annual Fleet Hours (3)	Annual Fleet Cost (4)	Active AC (5)	Cost/AC /Year (6)
4-eng wide-body	3,617.0	7.2340	554,706	$2,263,187	186	$12,168
4-eng narrow-body	2,104.0	4.2080	344,187	816,863	234	3,491
3-eng wide-body	3,003.5	6.0070	982,704	3,329,350	330	10,089
3-eng narrow-body	1,817.0	3.6340	1,612,445	3,304,829	906	3,648
2-eng wide-body	1,716.5	3.4330	997,548	1,931,464	274	7,049
2-eng narrow-body	1,282.0	2.5640	7,237,651	10,466,338	2,706	3,868
Weighted annual incremental fuel cost per aircraft						$4,770

(1) Total fuel burn. Washington Consulting Group, *Impact of Weight Changes* on Aircraft Fuel Consumption, January 12, 1994, pp 4-9.
(2) Incremental fuel consumption [column (1) times 0.0021.
(3) Federal Aviation Administration, *FAA Statistical Handbook of Aviation, Calendar Year* 1994, Table 5.3. (Note: these data have not been published, but are available on the FAA website.)
(4) Column (2) times column (3) times $0.564 [the air carrier price of jet fuel in 1996 dollars]. Federal Aviation Administration, *FAA Aviation Forecasts, Fiscal Years* 1996-2007, Table 6. --Baseline Air Carrier Forecast Assumptions, p 1X-8.
(5) *FAA Statistical Handbook of Aviation, Calendar Year* 1994, Table 5.2.
(6) Average incremental fuel cost per aircraft per year is computed by dividing total incremental annual cost [the sum of column (4)] by the total number of in-service aircraft [the sum of column (5)].

b. Engines with inlet areas less than 2,092 square inches

The proposed rule would have a negligible effect on operating and production costs for engines with inlet areas less than 2,092 square inches: proposed medium bird weights are essentially unchanged for engines with inlet areas between 620 and 2,092 square inches, and are lower for engines with inlet areas less than 620 square inches. Table 2 summarizes the cost effects of the proposed rule.

Table 2.--Summary of Incremental Costs by Provision and Engine Inlet Size

NPRM Provision	Large Engines (>~2,100 in^2)	Small Engines (<~2,100 in^2)
Large Bird Req.s Eng. -Front Impact §33.76(a)(3)	Component test: $250,000	Component test: $250,000
Revised bird wts. §33.76(b)	Negligible cost effect	Negligible cost effect
§33.76(b)(4)	Existing practice	Existing practice
Med Bird Req.s Eng. -Front Impact	Existing practice	Existing practice.
Revised bird wts and speeds	Reduced fan efficiency	Negligible cost effect
Full-fan assembly §33.76(c)(3)	Component test and/or analysis: $250,000	Not applicable
Hot day condition	Negligible cost effect	Negligible cost effect
20 min. run-on §33.76(c)(8)-(9)	Negligible cost effect	Negligible cost effect

B. Incremental benefits

1. Benefits of reduced fatalities and injuries

The annual benefits associated with the reduced risk of casualties, B_c, can be computed as:

$$B_c = (D \times (P_o - P_n)) \times [((P_f \times N) \times V_f) + (((P_i \times N) \times V_i)]$$

Where,

D = The number of departures per year (approximately 1,500)

P_c = The rate of a bird ingestion-related accidents per departure under current regulations

P_n = The rate of a bird ingestion-related accident per departure under the NPRM

N = The average number of occupants per airplane departure

P_f = The conditional probability of being killed given an accident

P_i = The conditional probability of being injured given an accident

V_f = The value of a fatality averted

V_i = The value of an injury averted

Accident probability estimates are based on historical information obtained from several sources including: 1) The FAA Accident/Incident Database System, 2) accident records from the National Transportation Safety Board (NTSB), 3) FAA Technical Center analyses of bird ingestion events, and 4) information submitted by engine manufacturers.

As noted above, bird ingestion events are not uncommon, occurring at a rate of approximately 204 ingestions per million aircraft operations. A very small fraction of this number result in a major failure condition. The FAA--using the sources cited above--documented 13 cases world-wide involving a large commercial jet transport in which ingested birds caused either a crash (five cases) or loss of power exceeding 25% to more than one engine (eight cases) for the 20-year period 1975-1994.[3] During this period, air carriers logged

[3] The accidents involved a DC-10 in 1975, a B737 in 1978, an A300B in 1986, a B737 in 1988, and a B707 in 1990. These totals do not include three incidents involving U. S. Air Force military variants of commercial transports. See Appendix I.

241.5 million departures.[4] Thus, a major failure condition occurs at a rate of approximately 5.4 events per 10^8 departures, and the accident rate is approximately 2.1 per 10^8.

Table 3.--Estimated Reduction in Accident Rate
(For a notional transport category airplane in 1996 dollars)

(1) Departures 1975-1992 (millions)	241.5
(2) Hull losses	5
(3) Est loss/million departures w/o rule	0.020;
(4) Est loss/million departures w/ rule	0.0021
(5) Est. risk reduction/mil. departures	0.0186
(6) Air Carrier departures/yr/AC (mil.)	0.00151

Line (1): Historical worldwide departures (see footnote 4).
Line (3): Ratio of lines (2) and (1).
Line (4): Estimate of risk reduction provided by ARAC.
Line (5): Difference between lines (3) and (4).
Line (6): Ratio of 1) 1992 departures for large certificated air carriers (source: Department of Transportation, Research and Special Programs Administration, *Air Carrier Traffic Statistics Monthly),* and 2) 1992 number of active aircraft (source: FAA, *Census of U.S. Civil Aircraft).*

According to an industry expert, the proposed rule is expected to reduce the accident rate by one order of magnitude or 90%. Therefore, the reduction in risk (the difference between the accident rate under the current regime and under the proposed rule) is approximately 1.9 per 10^8. (See Table 3)

Projecting the numbers of prevented injuries is problematic, however, since this benefit depends on trends in aircraft size and usage. Using estimates

[4] World-wide departures are from the International Civil Aviation Organization (ICAO) *Civil Aviation Statistics of the World* (various issues). Estimates of the rule's potential benefits are based on world-wide service records for a number of reasons: 1) Manufacturers were not able to provide engine operating data broken into domestic and foreign components. 2) While bird control procedures differ between countries, many researchers point out that underreporting in the U.S. makes it difficult to draw conclusions regarding the differences between domestic and foreign ingestion rates. Banilower, *op. cit.,* for example, concludes that "it is unlikely that domestic engine events were underreported relative to foreign by less than 20 percent. The best estimate is that underreporting is over 100 percent, but may be 200 percent or higher."

from the most recent *FAA Aviation Forecast,* this analysis assumes that the average air carrier airplane has 161 seats and a load factor of 66%. The historical data show that approximately 7.7% of passengers and crew involved in a bird strike accident are killed; an additional 4.7% are injured (see Table 4).

Table 4.--Historical Distribution of Injuries
For Bird Ingestion Accidents

Fatalities/Injuries	
Total passengers/crew	452
Fatalities	35
Injuries	21
Prob(Fatality,Injury | accident)	
Fatalities	0.0774
Injuries	**0.0465**

Table 5.--Benefits of averted fatalities and injuries
(For a representative transport category airplane in 1996 dollars)

(1) Est. risk reduction per mil. departures	0.0186
(2) Air Carrier departures/yr/AC (mil.)	0.0015
(3) Average seats per airplane	161
(4) Average load factor	**66%**
(5) Crew for notional airplane	6
(6) Total Occupants	112
(7) Prob(killed | accident)	**0.0774**
(8) Prob(injured | accident)	**0.0465**
(9) Value of a fatality averted	$2.7m
(10) Value of an injury averted	$518K
(11) Expected annual benefit from averted fatalities	**$654**
(12) Expected annual benefit from averted injuries	**$75**

Lines (1) and (2): See Table 3.
Lines (3) and (4): Average seating capacity and load factor for Form 41 air carriers in 1996. See: FAA, *FAA Aviation Forecasts, Fiscal Years 1996-2007,* Table 6. --Baseline Air Carrier Forecast Assumptions, p 1X-8.). Also see footnote 5.
Line (6): Line (5) plus product of lines (3) and (4).
Lines (7) and (8): See Table 4.
Lines (9) and (10): Official DOT values.
Line (11): Product of lines (1), (2), (6), (7), and (9).
Line (12): Product of lines (1), (2), (6), (8), and (10).

The projected number of fatalities per bird ingestion-related airplane crash, then, is equal to the number of seats times the load factor times the historical percentage of people killed in such accidents (161 x 66% x 7.7% ≅ 8). Similarly, the expected number of injuries given a bird ingestion-related accident is (161 x 66% x 4.7% ≅ 5). Table 5 computes the annual expected per airplane benefit associated with a reduction in the risk of fatalities or injuries for a representative passenger airplane.

2. Benefits of avoided property loss

The annual per airplane benefit of avoided property loss can similarly be computed as:

$$B_p = (D \times (P_c - P_n)) \times V$$

Assuming that the replacement value, V, of a typical commercial transport airplane is $23.5 million; the annual per airplane benefit from avoided aircraft loss is approximately $657.[5]

3. Benefits of reduced maintenance costs

According to an industry expert, the proposed rule would also have the effect of reducing repair costs 90% by raising the damage threshold (the bird weight

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[5] The benefit-cost analysis is based on a notional twin engine jet airplane. FAA estimates its price at $47 million in 1996 dollars. (Based on a survey of new airplane prices compiled by an insurance consultancy. See: Airclaims Limited, *International Aircraft Price Guide,* Winter, 1996.) Replacement cost is assumed to be one-half the new airplane value. See: FAA, *Economic Values of Evaluation of Federal Aviation Administration Investment and Regulatory Programs,* Report FAA-APO-90-10, October, 1989.

which produces engine damage) by one pound from 0.5 pounds to 1.5 pounds.[6] Estimating these savings, however, is difficult since bird ingestion damage is probabilistic. That is, the ingestion of a bird of a given weight will cause damage of a given severity only with some probability (with smaller birds less likely to cause damage than larger birds). Moreover, it is not clear that all types of damage would be uniformly affected by the new standards. One could argue, then, that mechanically applying the 90% rule to all repair costs overstates the potential savings. Ideally, estimating this benefit would involve the evaluation of test and in-service data comparing engine designs certificated under the current and proposed regulations. In the absence of these data, FAA makes some simplifying and conservative assumptions (based on historical bird ingestion information) to derive an estimate of the savings arising from reduced repair costs.

In this approach, the expected value of savings due to reduced bird ingestion damage is equal to the product of the reduction in the probability of damage given the ingestion of a bird of given weight, r(w), times the probability of ingesting a bird of that weight, $P_i(w)$, times the cost of repair, C(w), summed over all bird weights:

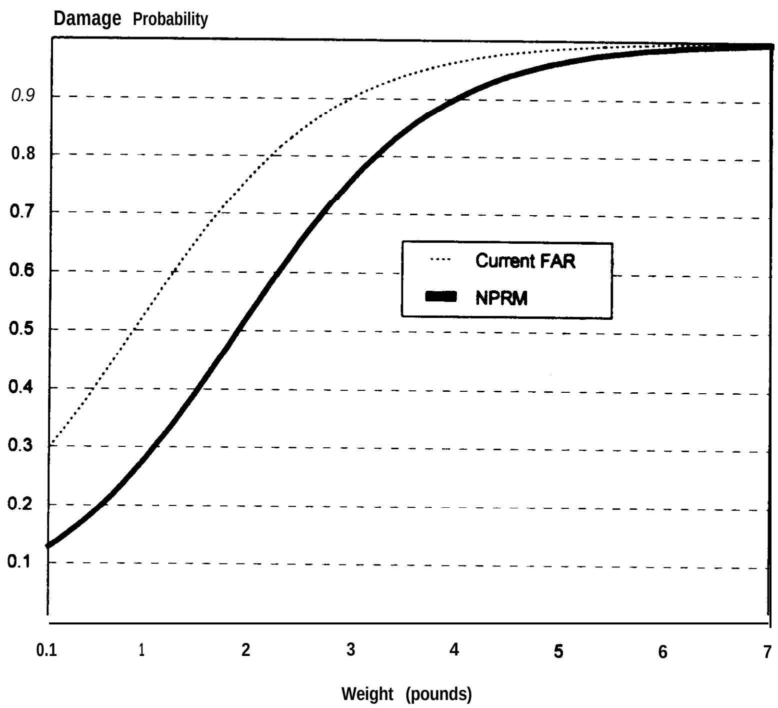
$$\sum_{w} r(w) P_i(w) C(w)$$

[6] This is a result of increasing the weight of the largest medium bird from 1.5 to approximately 2.5 pounds.

In order to estimate the reduction in the likelihood of engine damage, the FAA postulates that the probability, $P_d(w)$, of damage given the ingestion of a bird of weight, w, can be described'by a logit model with parameters μ and σ.[7]

$$P_d(w) = \frac{1}{1+\exp\left\{-\left(\frac{\pi}{\sqrt{3}}\right)\left(\frac{w-\mu}{\sigma}\right)\right\}}$$

Figure 1.--Probability of Damage by Bird Weight



Damage probability curves under current Federal Aviation Regulations and under the proposed NPRM are illustrated in Figure 1. The shift in $P_d(w)$ in figure 1, then, is a measure of the rule's effect on the likelihood of engine damage as a result of increasing the damage threshold.[8]

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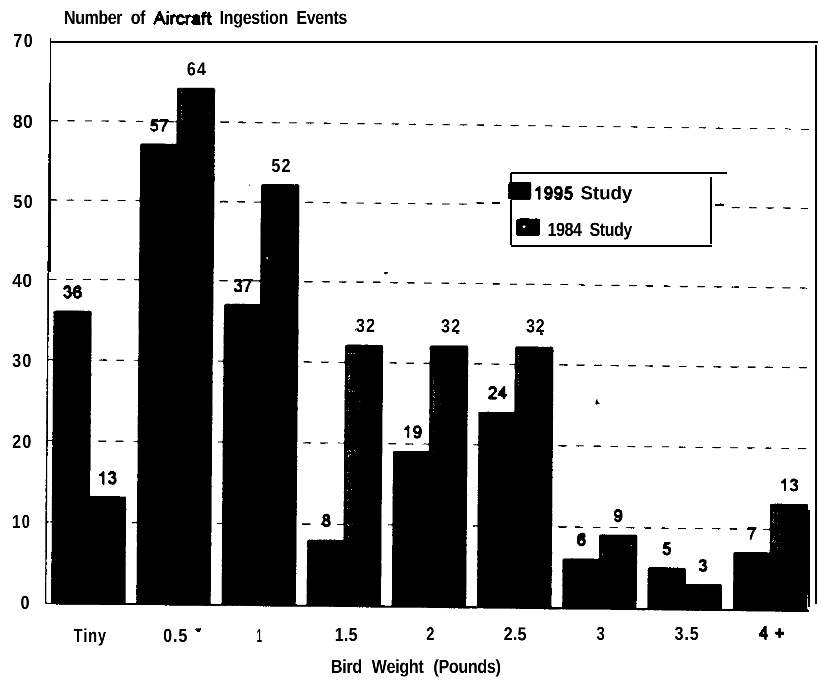
7 Logit analysis is applied since the dependent variable is dichotomous; that is, damage either occurs or does not occur. A computer program estimates the model by computing parameters that maximize the likelihood of obtaining the observed sample.

8 The equation was estimated using bird ingestion and engine damage data for the period January 1989-August 1991. The data were collected by engine manufacturers and compiled by the FAA Technical Center (see Banilower, *op. cit.).* The estimated values of μ and σ are 0.9035 and 1.7033, respectively

Figure 2.--Frequency Distribution of.Bird Ingestion Events
By Weight-Class



The equations illustrated in Figure 1, in turn, are used to estimate the reduction in the risk of engine damage for discrete weight-classes of birds.[9] The distribution of bird ingestions by weight class is computed directly from the Technical Center 1995 study sample (see Figure 2).[10] Average repair costs, assumed to be an increasing function of bird weight, are estimated using repair cost data collected by the Air Transport Association and

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(where bird weight is measured in pounds). The effect of the proposed rule is approximated by shifting μ by one pound.

[9] Following the convention used in FAA Technical Center studies of bird ingestion, these categories are "Tiny", *0.5* lb, 1.0 lb, 1.5 lb, 2 lb, etc.

[10] Banilower, *op. cit.* An analysis of the 1984 sample appears in Frings, Gary, *A Study of Bird Ingestions Into Large High Bypass Ratio Turbine Aircraft Engines,* U.S. Department of Transportation, Federal Aviation Administration, DOT/FAA/CT-84/13. In this regulatory evaluation the weight distribution of all bird ingestion events is assumed to equal the distribution of those events for which bird weight could be determined.

Technical Center bird ingestion damage information. (See Appendix II.) Assuming an annual average of 1,500 departures, the expected savings from reduced repair costs per aircraft per year are $4,654. (The calculations are shown in Table 6.)

Table 6.--Calculation of the Rule's Effect on Repair Costs

Bird class (1)	Ingest Rate (2)	$P_d(w)$ Before (3)	$P_d(w)$ After (4)	Before -after (5)	Rate reduct. (6)	Avg repair cost	Saving/ mil ops (7)	Saving/ AC/year (8)
Tiny	38.57	0.3691	0.1678	0.2013	7.76	$67,378	$522,992	$784
0.5	61.33	0.3942	0.1832	0.2110	12.94	$66,989	$866,739	$1,300
1.0	39.84	0.5257	0.2765	0.2492	9.93	$99,531	$660,573	$991
1.5	8.53	0.6537	0.3942	0.2595	2.21	$68,408	$151,406	$227
2.0	20.55	0.7627	0.5257	0.2371	4.87	$72,254	$351,983	$528
2.5	25.92	0.8456	0.6538	0.1919	4.97	$77,492	$385,408	$578
3.0	6.32	0.9031	0.7627	0.1404	0.88	$83,423	$74,031	$111
3.5	5.37	0.9408	0.8456	0.0952	0.51	$89,372	$45,693	$69
4.0+	7.59	0.9643	0.46 0.9031	0.0612	$94,[illegible]	$94,823	$44,051	$66
Totals								$4,654

(1) Bird size class (see Banilower, *op. cit.*, p 30, Table 4.6).
(2) Estimated ingestion rate by size using Banilower data (per million aircraft operations).
(3) Probability of damage by weight under current FAR (from Banilower data).
(4) Probability of damage computed by shifting damage threshold.
(5) Measure of risk reduction [column (4) minus column (5)] (per million aircraft operations).
(6) Reduction in the number of repairs per million aircraft operations [column (2) times column (5)].
(7) Estimated per aircraft savings per million aircraft operations
(8) Estimated annual per aircraft savings. Assumes 1,481 departures per year. *FAA Statistical Handbook of Aviation, Calendar Year 1992.*

4. Unquantified benefits

Another benefit, while difficult to quantify, has important market impacts. Current regulations impose a substantial regulatory burden on manufacturers of small turbine engines. For example, the medium bird test for an engine with an inlet area of 301 square inches requires twice the bird mass (two 1.5 pound birds) as the medium bird test for an engine with a 299 square inch inlet area (one 1.5 pound bird). This, in turn, places restrictions on the size of aircraft powered by small turbine engines. One manufacturer of small jet aircraft reported that one of its aircraft designs explicitly takes into consideration the size of the inlet and, in particular, the 300 square inch threshold.

In view of the bird ingestion history of small turbine engines, the proposed rule relaxes the medium bird weight requirements. Theoretically, this will reduce the disincentives that currently make some engines (and, therefore, some aircraft) uneconomical to produce. As a result, consumers would benefit from a wider offering of products with better performance.

C. Comparison of benefits and costs

In order to compare the costs and benefits of the proposed rule, the evaluation considers a hypothetical representative engine certification. As noted earlier, the engines are assumed to be installed on a notional twin-engine jet transport with a seating capacity of 161. In addition, this example assumes that: 1) the discount rate is 7%, 2) incremental engine certification testing costs are incurred in years 0 and 1 (these are the costs associated with two additional component tests), 3) production of the engines commences in year 2, 4) engines are installed in aircraft and enter service in year 3, 5) there are two engines per aircraft, 6) each engine has a 15-year service life, 7) 24 engines are produced per year for ten years, so that there are 240 total engines and 120 airplanes per certification. Under these assumptions, the expected discounted benefits of the proposed rule would exceed discounted costs by a factor of 1.11. The calculations are shown in Table 7.

Table 7.--A Comparison of Incremental Benefits and Costs For a Representative, Hypothetical Engine Certification (thousands of dollars)

				Incremental Costs				Incremental Benefits				
T	Disc Rate	Eng Prod	AC in Srv	Cert Cost	Op Cost	Tot. Cost	Disc Cost	Maint. Ben	Prop Ben	Inj Ben	Tot Ben	Disc Ben
0	1.00	0	0	250	0	250	250	0	0	0	0	0
1	0.93	0	0	250	0	250	234	0	0	0	0	0
2	0.87	24	0		0	0	0	0	0	0	0	0
3	0.82	24	12		57	57	47	56	8	17	72	59
4	0.76	24	24		114	114	87	112	16	26	145	111
5	0.71	24	36		172	172	122	168	24	35	217	155
6	0.67	24	48		229	229	153	223	32	44	290	193
7	0.62	24	60		286	286	178	279	39	52	362	226
8	0.58	24	72		343	343	200	335	47	61	435	253
9	0.54	24	84		401	401	218	391	55	70	507	276
10	0.51	24	96		458	458	233	447	63	79	580	295
11	0.48	24	108		515	515	245	503	71	87	652	310
12	0.44		120		572	572	254	558	79	87	725	322
13	0.42		120		572	572	238	558	79	87	725	301
14	0.39		120		572	572	222	558	79	87	725	281
15	0.36		120		572	572	207	558	79	87	725	263
16	0.34		120		572	572	194	558	79	87	725	246
17	0.32		120		572	572	181	558	79	87	725	229
18	0.30		108		515	515	152	503	71	79	652	193
19	0.28		96		458	458	127	447	63	70	580	160
20	0.26		84		401	401	104	391	55	61	507	131
21			72		343	343	83	335	47	52	435	105
22			60		286	286	65	279	39	44	362	82
23			48		229	229	48	223	32	35	290	61
24			36		172	172	34	168	24	26	217	43
25			24		114	114	21	112	16	17	145	27
26			12		57	57	10	56	8	9	72	12
Tot				500	8,586	9,086	3,906	8,377	1,183	1,312	10,872	4,333

IV. Regulatory Flexibility Determination

The Regulatory Flexibility Act of 1980 establishes "as a principle of regulatory issuance that agencies shall endeavor, consistent with the objectives of the rule and of applicable statutes, to fit regulatory and informational requirements to the scale of the businesses, organizations, and governmental jurisdictions subject to regulation." To achieve that principle, the Act requires agencies to solicit and consider flexible regulatory proposals and to explain the rationale for their actions. The Act covers a wide range of small entities, including small businesses, not-for-profit organizations and small governmental jurisdictions.

Agencies must perform a preliminary analysis of all proposed rules to determine whether the rule will have a significant economic impact on a substantial number of small entities; if the determination is that it will, the agency must prepare an initial regulatory flexibility analysis (RFA).

However, if after a preliminary analysis for a proposed or final rule, an agency determines that a rule is not expected to have a significant economic impact on a substantial number of small entities, Section 605(b) of the 1980 act provides that the head of the agency may so certify. The certification must include a statement providing the factual basis for this determination, and the reasoning should be clear.

The FAA has conducted the required preliminary analysis of this proposal and determined that it will not have a significant economic impact on a manufacturing costs. In light of the fact that there is only one known small business manufacturing turbine aircraft engines, and that manufacturer is not expected to be affected by the proposed rule in the foreseeable future, this analysis will assume that manufacturing costs imposed by this proposed rule will be passed on to operators who purchase the new engines and analyze these costs on small operators.

Aircraft operators would incur slightly higher engine prices, plus pay increased operating or fuel costs due to the small decrease in engine efficiency described in the full regulatory evaluation. According to FAA data, there are about 3,000 air carriers having less than 1,500 employees--approximately 100 part 121 (or dual 121/135 certificate) air carriers, and 2,900 part 135 air carriers

Assuming conservatively that: 1) all incremental certification costs are passed on to the buyer/operator, 2) the manufacturer recovers incremental certification costs by applying a uniform price increase to 240 engines produced during a ten year production run, and 3) that the discount rate is 7 percent; then the FAA estimates that average engine prices will increase by approximately $3070 per larger engine and $1587 per smaller engine. When these costs are amortized over the 15-year life of an engine (again, assuming a 7% discount rate), the incremental annualized cost per engine is approximately $315 and $163 for larger and smaller engines, respectively. Therefore, assuming a typical airplane has two engines, the incremental annualized cost for a large airplane is approximately $630 and the incremental annualized cost for a smaller airplane is approximately $326.

substantial number of small entities. The following statement summarizes the basis for this determination.

The proposed rule would apply only to newly designed turbine aircraft engines certificated in the future. Each new engine certification could affect two types of small entities.

First, the manufacturer would be required to perform additional analysis or testing to demonstrate that the proposed new bird ingestion requirements are met. There are currently 9 turbine aircraft engine manufacturers with headquarters in the U.S. (this count includes subsidiaries of foreign entities, and consortiums of domestic and/or foreign entities).[11] Information available to the FAA at this time indicates that only one of these--a U.S. manufacturer of small turbine engines--has less than 1,500 employees and therefore qualifies as a small business under guidelines issued by the Small Business Administration.

It is difficult to estimate total costs to this single manufacturer because these costs are a function of the number of engines certificated. This manufacturer is not expected to conduct bird ingestion testing in the foreseeable future. In view of this uncertainty, this analysis focuses on per engine costs for both manufacturers and operators.

The proposed rule is estimated to add about $250,000 for a small engine type as currently manufactured by the single small entity (these are one time costs per certification). The FAA estimates that the proposed rule would impose no

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11 Aviation *Week and Space Technology Aerospace Sourcebook,* January 8, 1996.

For larger engines, the rule will also increase annual airplane operating costs as a result of the proposed medium bird ingestion requirements (these requirements would have a negligible effect on smaller engines). On average, annual operating costs per large airplane, therefore, would increase by approximately $4,770 (see Table 1). However, the reduction in average annualized maintenance costs, associated with the more damage resistant engines that would be developed as a result of this rule, would almost completely offset incremental operating costs. These reduced maintenance costs are **described** more fully in the full regulatory evaluation.

Total annualized costs for operators of larger and smaller airplanes would therefore be approximately $630 and $326 per airplane, respectively. Consequently, the FAA makes an initial certification that the proposed rule would not have a significant economic impact on a substantial number of small entities.

V. International Trade Impact Assessment

The rule would have little or no effect on trade for either U.S. firms marketing turbine engines in foreign markets or foreign firms marketing turbine engines in the U.S.

Appendix I: Bird ingestion events involving large jet transports

Includes: 1) accidents, 2) events involving multiple engine power loss of 25% or greater, 3) military variants of commercial jet transports (although these cases are *not* used in the accident/benefit analysis). Airplane and location detail are omitted in the case of proprietary data.

Year	Location	Airplane	Description
1975			Bird ingestion led to aborted take-off. No fatalities or injuries.
1975	US	DC10-30	During take-off roll, struck seagulls. Rejected takeoff. Uncontained engine failure. Aircraft destroyed by fire. 128 passengers, 3 crew. **No** fatalities or injuries.
1977			Bird ingestion led to aborted take-off. **No** fatalities or injuries.
1978	Belgium	B737-200	Aircraft overran runway during rejected takeoff following bird ingestion. Aircraft destroyed by fire. 3 crew. No fatalities or injuries
1979			Air turnback following bird ingestion. No fatalities or injuries.
1982			Bird ingestion on approach. No fatalities or injuries.
1983			Aborted take-off following bird ingestion. **No** fatalities or injuries.
1986	India	A300B	Rejected takeoff following bird ingestion. Aircraft declared a hull loss. 185 passengers, 17 crew. **No** fatalities or injuries.
1987			Aborted take-off following bird ingestion. **No** fatalities or injuries.
1987			**Military.** Air turnback following bird ingestion. **No** fatalities or injuries.
1988	Ethiopia	B737-200	Crash during air turnback following bird ingestion into both engines. Aircraft destroved. 105 passengers/crew. 35 fatalities, 21 injuries.
1989			Aborted take-off following bird ingestion. **No** fatalities or injuries.
1990	Ethiopia	B707-300	Rejected take-off following bird ingestion. Aircraft destroyed by fire. 4 crew. **No** fatalities, 1 serious injury.
1995	us	**E-3** AWACS	**Military.** Aircraft crashed shortly after take-off following multiple engine bird ingestion. Aircraft destroyed. 24 aboard, all killed.
1996	Greece	**E-3** AWACS	**Military. Rejected** take-off following bird ingestion. Aircraft not repaired. **No** fatalities or injuries.
	Summary		**Commercial Hull Losses** Number of Hull Losses: 5 Passengers/crew: 452 Number of fatalities: 35 Number of injuries: 21

Appendix II: Estimation of repair costs as a function of bird weight

About one-half of bird ingestion events result in damage to the engine, with the probability of damage increasing as bird weight increases. Generally, the severity of damage also increases with bird weight. For example, the 1995 FAA Technical Center study (see footnote 1) observes that for events involving birds weighing 1 pound or less, less than half of the cases of damage were classified as "severe." On the other hand, for events involving birds weighing more than 1 pound, 68% of the cases of damage were classified as "severe."[12]

The available data did not permit a direct estimate of the relationship between repair costs and bird weight (for example, using ordinary least squares). Instead, a repair cost "function" was estimated as follows:

1) costs for different types of repairs were computed as averages of estimates reported by operators (these data were compiled by the Air Transport Association). Average costs are summarized in Table AII.l.

Table AII.1.--Average Repair Costs for Engine Damage Due to Bird Ingestion[13]

Damage	Average Cost
Nicked Fan Blade	$ 100
Bent/Broken Fan Blade	$ 4,000
Core Damage	$150,000
Nose Cowl	$195,000
Nacelle	$200,000

12 The Technical Center database classifies damage as "minor" or "severe." Examples of minor damage include fan blade leading edge distortion, 1 to 3 bent or dented fan blades, or acoustic panel damage. Examples of severe damage include core or turbine damage.

13 These costs include labor and material costs, but do not include the revenue lost from removing an airplane from service.

2) These values were applied to descriptions of engine damage contained in the Technical Center database. This yields an average repair cost for "severe" damage events of approximately $114,000. Similarly, the average repair cost for "minor" damage events is $12,000.

3) The relationship between the probability of a "severe" event and bird weight was estimated via a logit model. Such models are used to estimate the relationship between the probability of an event and an explanatory variable. In this case, the results were used to estimate the share of severe events relative to the total number of bird ingestion events.

4) Repair costs for any weight-class, then, are the sum of "severe damage" and "minor damage" repair costs weighted by the relative share of severe and minor events. These calculations are summarized in the table below.

Table AII.2.--Calculation of Average Repair Costs by Bird Weight

Weight	Damage Probability		"Severe" Share	Cost Function
Tiny	0.3691	0.2004	0.5429	$67,378
0.5	0.3942	0.2125	0.5391	$66,989
1.0	0.5257	0.2810	0.5346	$99,531
1.5	0.6537	0.3615	0.5530	$68,408
2.0	0.8456	0.4506	0.5907	$72,254
		0.5429	0.6421	$77,492
3.0	0.9031	0.6324	0.7002	$83,423
3.5	0.9408	0.7136	0.7586	$89,372
4.0+	0.9643	0.7830	0.8120	$94,823